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Pacific Outer Continental Shelf

OCS Report
MMS 87-0108

NORTHERN AND CENTRAL CALIFORNIA

Lease Sale/May 14, 1963

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MMS U.S. Department of the Interior
Minerals Management Service

ORIGINAL

Pacific Outer Continental Shelf

OCS Report
MMS 87-0108

NORTHERN AND CENTRAL CALIFORNIA

Lease Sale/May 14, 1963

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U.S. Department of the Interior
Minerals Management Service

October 1987

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PACIFIC OCS LEASE SALE, MAY 14, 1963, NORTHERN AND CENTRAL CALIFORNIA

INTRODUCTION

Between September 1963 and September 1967, twenty exploratory wells (19 original holes and 1 redrill) were drilled on northern and central California Outer Continental Shelf (OCS) leases awarded after the first OCS oil and gas lease sale on the Pacific coast (now referred to as Sale P1) held on May 14, 1963. The wells were drilled in four of the six sedimentary basins recognized in coastal California north of Point Conception (fig. 1). Indications of hydrocarbons (shows) were encountered in most of the wells in three of the basins, but none of the shows were considered at that time to be of commercial quality. The economic climate for heavy sour crude oil, combined with high development and transportation costs, imposed severe limitations on possible development. Improvements in the hydrocarbon price structure and drilling and production technologies since then have dramatically changed oil industry attitudes toward the hydrocarbon development potential of the Pacific OCS. The 1963 lease sale and subsequent exploration helped define the more promising areas for future consideration.

This report supersedes and is a modification of the Minerals Management Service's "Technical Monograph" entitled "Pacific OCS Lease Offering, 1963, Northern and Central California," printed in 1983. It summarizes the leasing and drilling histories, geology, and hydrocarbon potential of the northern and central California OCS.

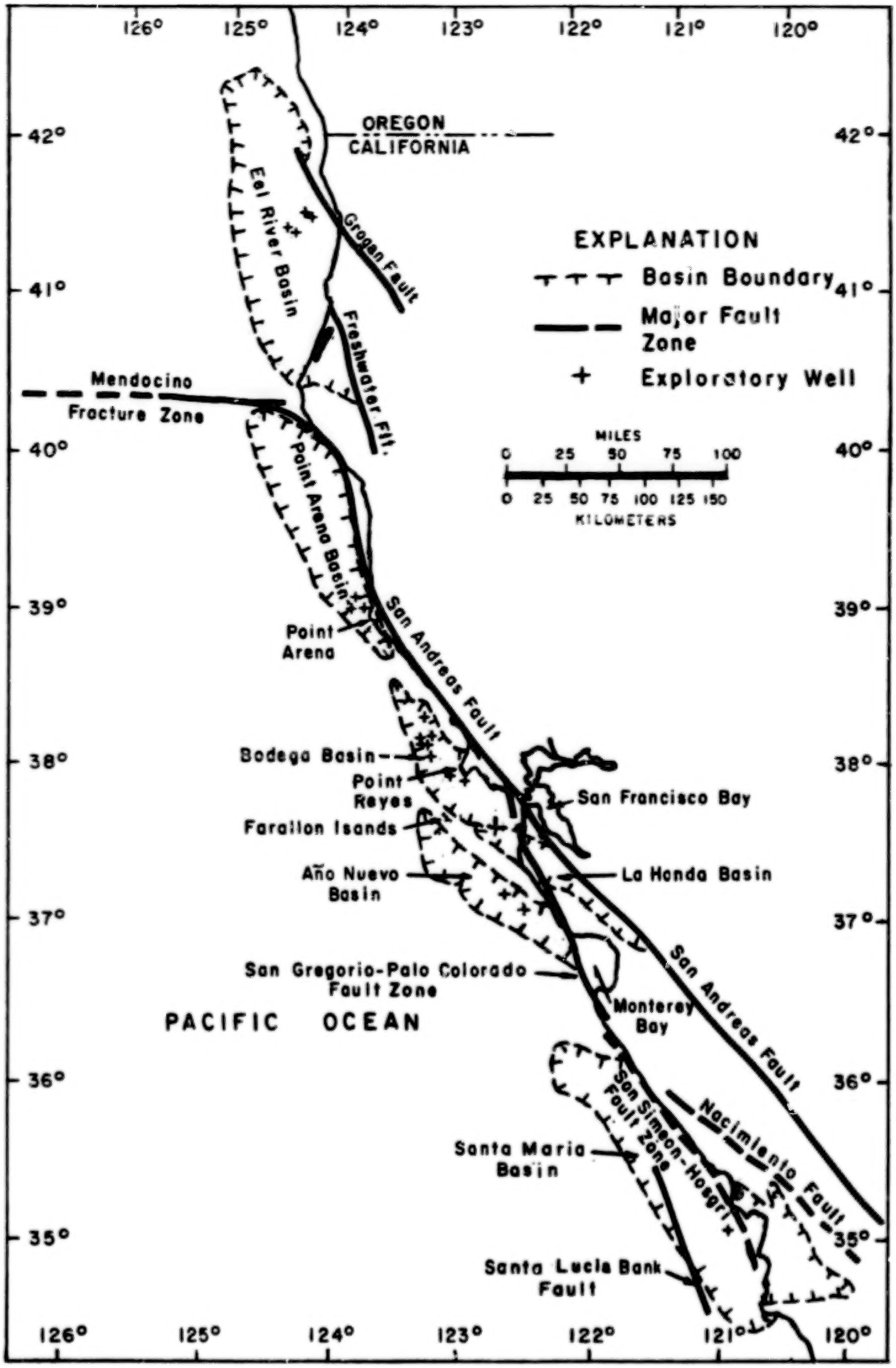

Figure 1. Sedimentary Basins and Major Faults.

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LEASING HISTORY

During the late 1950's and early 1960's, while its competitors were concentrating their offshore exploration efforts in southern California, Shell Oil Company carried out an extensive petroleum exploration program offshore northern and central California. This program consisted of geophysical surveying, seafloor sampling, and shallow core hole drilling. These efforts were joined by those of Standard Oil Company of California (now Chevron USA, Inc.), Humble Oil and Refining Company (now Exxon Company, Inc.), and Superior Oil Company.

On January 30, 1962, the Federal Government called for nominations for Outer Continental Shelf (OCS) blocks covering four million acres in the area off northern and central California. One hundred seventy-four blocks, totaling 900,000 acres, were nominated. These blocks, comprising 5,760 acres per block, and defined by California Coordinate System (Lambert) coordinates,* were grouped into four geographic areas: Eureka, consisting of the offshore Eel River sedimentary basin (figs. 2 and 3); Point Arena, consisting of the Point Arena and northern Bodega basins (fig. 4); San Francisco, consisting of southern Bodega, La Honda (Inner Santa Cruz), and Ano Nuevo (Outer Santa Cruz) basins (fig. 5); and Morro Bay, consisting of the offshore Santa Maria basin (fig. 6).

On May 14, 1963, the first Federal OCS oil and gas lease sale on the Pacific coast was held. Tables 1 & 2 summarize the activities of the sale. A total of 129 tracts, encompassing 669,777 acres, were offered for lease (figs. 2-6). Of these, 57 tracts (312,945 acres) were leased for a total bonus of $12,807,587. A single bid $250 by an individual bidder on a 30-acre tract north of Point Arena, was the only bid rejected. The two highest

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* In subsequent northern and central California offerings, blocks have been measured in metric units in the Universal Transverse Mercator (UTM) System.

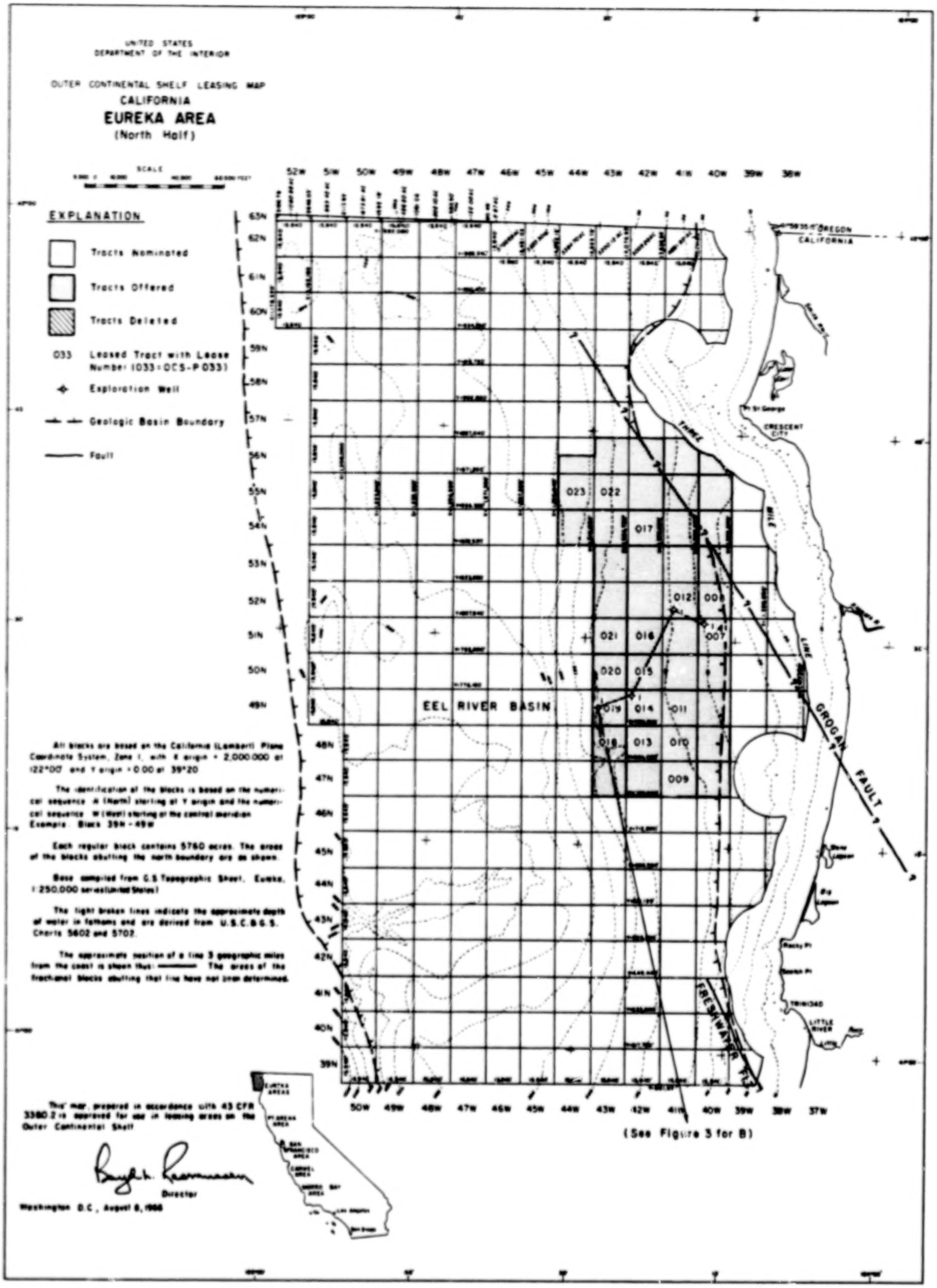
UNITED STATES
DEPARTMENT OF THE INTERIOR
OUTER CONTINENTAL SHELF LEASING MAP
CALIFORNIA
EUREKA AREA
(North Half)
SCALE
EXPLANATION
Tracts Nominated
Tracts Offered
Tracts Deleted
033 Leased Tract with Lease Number (033=OCS-P 033)
Exploration Well
Geologic Basin Boundary
Fault
52W
51W
50W
49W
48W
47W
46W
45W
44W
43W
42W
41W
40W
39W
38W
37W
63N
62N
61N
60N
59N
58N
57N
56N
55N
54N
53N
52N
51N
50N
49N
48N
47N
46N
45N
44N
43N
42N
41N
40N
39N
023
022
017
012
008
021
016
007
020
015
019
014
011
018
013
010
009
EEL RIVER BASIN
OREGON
CALIFORNIA
Pt St George
CRESCENT CITY
THREE MILE LINE
GROGAN FAULT
FRESHWATER FLT
Rocky Pt
Patrick Pt
TRINIDAD
LITTLE RIVER
All blocks are based on the California (Lambert) Plane Coordinate System, Zone I, with X origin = 2,000,000 at 122°00' and Y origin = 0.00 at 39°20
The identification of the blocks is based on the numerical sequence N (North) starting at Y origin and the numerical sequence W (West) starting at the central meridian Example: Block 39N-49W
Each regular block contains 5760 acres. The areas of the blocks abutting the north boundary are as shown.
Base compiled from G.S Topographic Sheet, Eureka, 1:250,000 series (United States)
The light broken lines indicate the approximate depth of water in fathoms and are derived from U.S.C.&G.S. Charts 5602 and 5702.
The approximate position of a line 3 geographic miles from the coast is shown thus: ——— The areas of the fractional blocks abutting that line have not been determined.
EUREKA AREAS
PT ARENA AREA
SAN FRANCISCO AREA
CARMEL AREA
MORRO BAY AREA
Los Angeles
San Diego
This map, prepared in accordance with 43 CFR 3380.2 is approved for use in leasing areas on the Outer Continental Shelf
Director
Washington D.C., August 8, 1966
(See Figure 3 for B)

Figure 2. Eureka Area (North Half).

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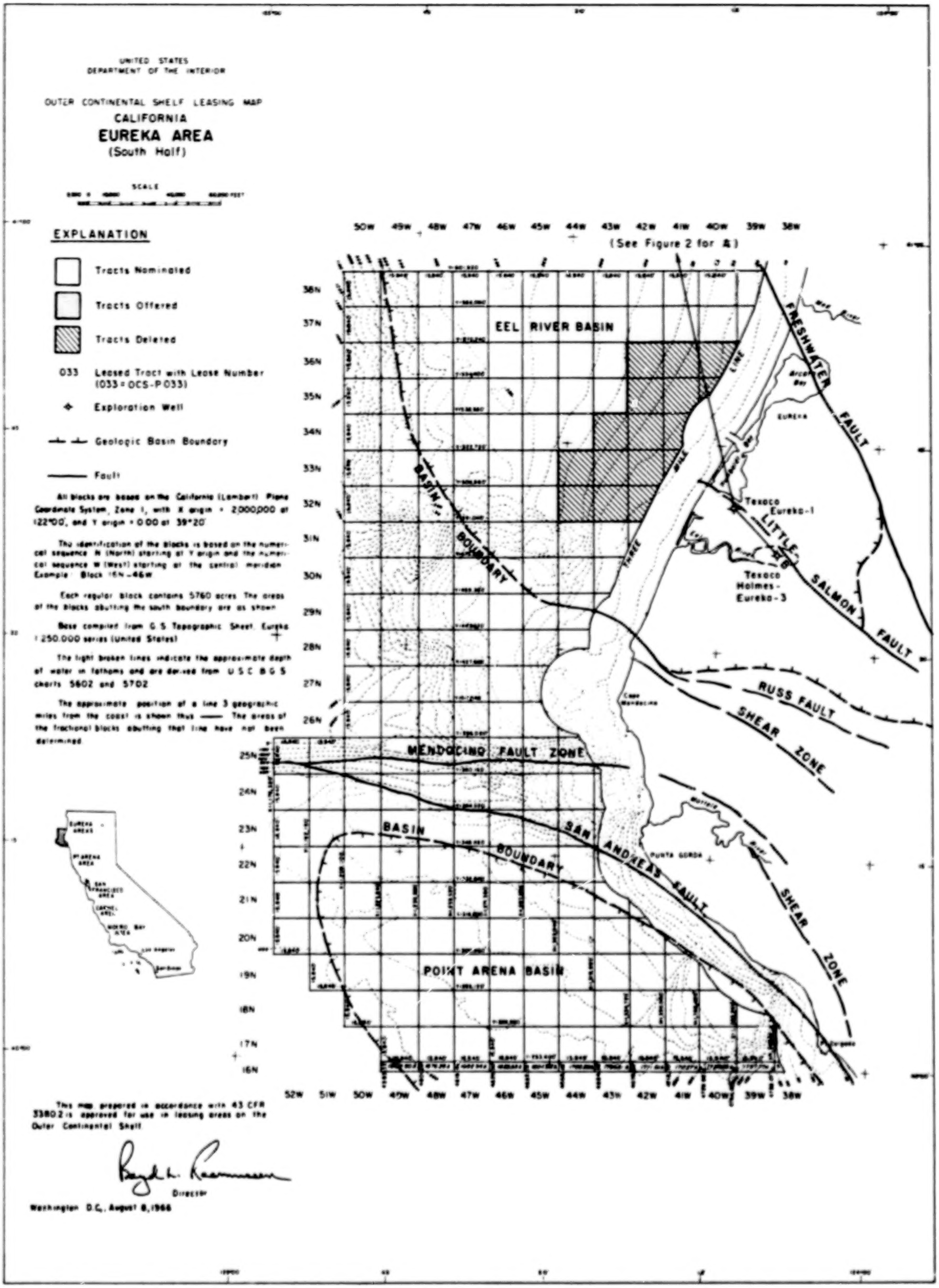
UNITED STATES
DEPARTMENT OF THE INTERIOR
OUTER CONTINENTAL SHELF LEASING MAP
CALIFORNIA
EUREKA AREA
(South Half)
SCALE
EXPLANATION
Tracts Nominated
Tracts Offered
Tracts Deleted
033 Leased Tract with Lease Number (033 = OCS-P 033)
Exploration Well
Geologic Basin Boundary
Fault
All blocks are based on the California (Lambert) Plane Coordinate System, Zone 1, with X origin = 2,000,000 at 122°00', and Y origin = 0.00 at 39°20'
The identification of the blocks is based on the numerical sequence N (North) starting at Y origin and the numerical sequence W (West) starting at the central meridian. Example: Block 15N-46W
Each regular block contains 5760 acres. The areas of the blocks abutting the south boundary are as shown
Base compiled from G.S. Topographic Sheet, Eureka 1:250,000 series (United States)
The light broken lines indicate the approximate depth of water in fathoms and are derived from U.S.C.&G.S. charts 5602 and 5702
The approximate position of a line 3 geographic miles from the coast is shown thus ——. The areas of the fractional blocks abutting that line have not been determined
This map prepared in accordance with 43 CFR 3380.2 is approved for use in leasing areas on the Outer Continental Shelf
Director
Washington D.C., August 8, 1966
(See Figure 2 for A)
50W 49W 48W 47W 46W 45W 44W 43W 42W 41W 40W 39W 38W
52W 51W 50W 49W 48W 47W 46W 45W 44W 43W 42W 41W 40W 39W 38W
38N 37N 36N 35N 34N 33N 32N 31N 30N 29N 28N 27N 26N 25N 24N 23N 22N 21N 20N 19N 18N 17N 16N
EEL RIVER BASIN
BASIN BOUNDARY
THREE MILE LINE
FRESHWATER FAULT
Arcata Bay
EUREKA
Texaco Eureka-1
Texaco Holmes-Eureka-3
LITTLE SALMON FAULT
RUSS FAULT
SHEAR ZONE
Cape Mendocino
MENDOCINO FAULT ZONE
SAN ANDREAS FAULT
PUNTA GORDA
BASIN BOUNDARY
SHEAR ZONE
POINT ARENA BASIN
EUREKA AREAS
PT. ARENA AREA
SAN FRANCISCO AREA
CAYUCOS AREA
MORRO BAY AREA
Los Angeles

Figure 3. Eureka Area (South Half)

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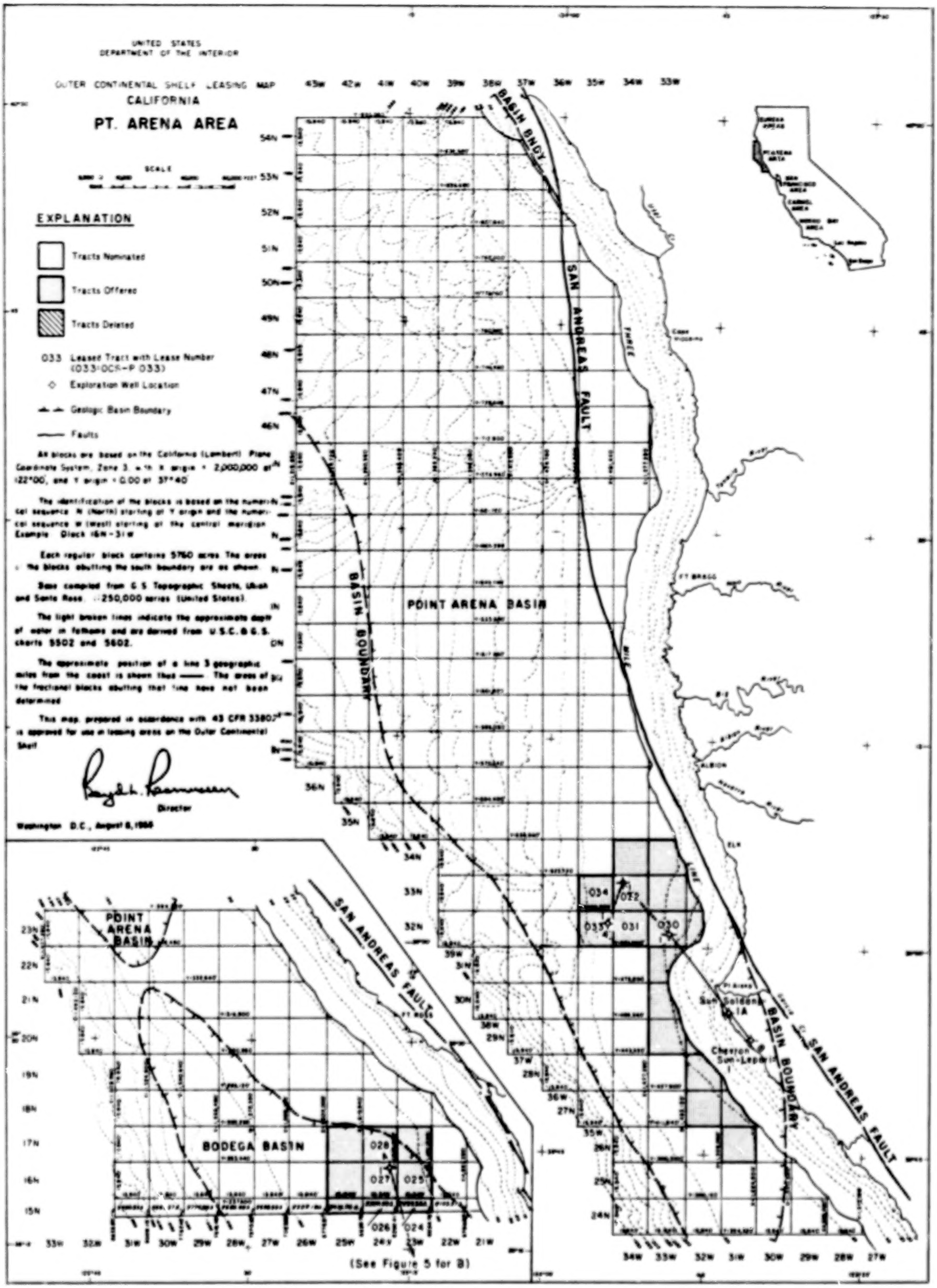

All blocks are based on the California (Lambert) Plane Coordinate System, Zone 3, with X origin = 2,000,000 at 122°00', and Y origin = 0.00 at 37°40'.

The identification of the blocks is based on the numerical sequence N (North) starting at Y origin and the numerical sequence W (West) starting at the central meridian. Example: Block 16N-31W

Each regular block contains 5760 acres. The areas of the blocks abutting the south boundary are as shown.

Base compiled from G.S. Topographic Sheets, Ukiah and Santa Rosa, 1:250,000 series (United States).

The light broken lines indicate the approximate depth of water in fathoms and are derived from U.S.C. & G.S. charts 5502 and 5602.

The approximate position of a line 3 geographic miles from the coast is shown thus ——. The areas of the fractional blocks abutting that line have not been determined.

This map, prepared in accordance with 43 CFR 3380.2 is approved for use in leasing areas on the Outer Continental Shelf.

Director

Washington D.C., August 8, 1966

Figure 4. Point Arena Area

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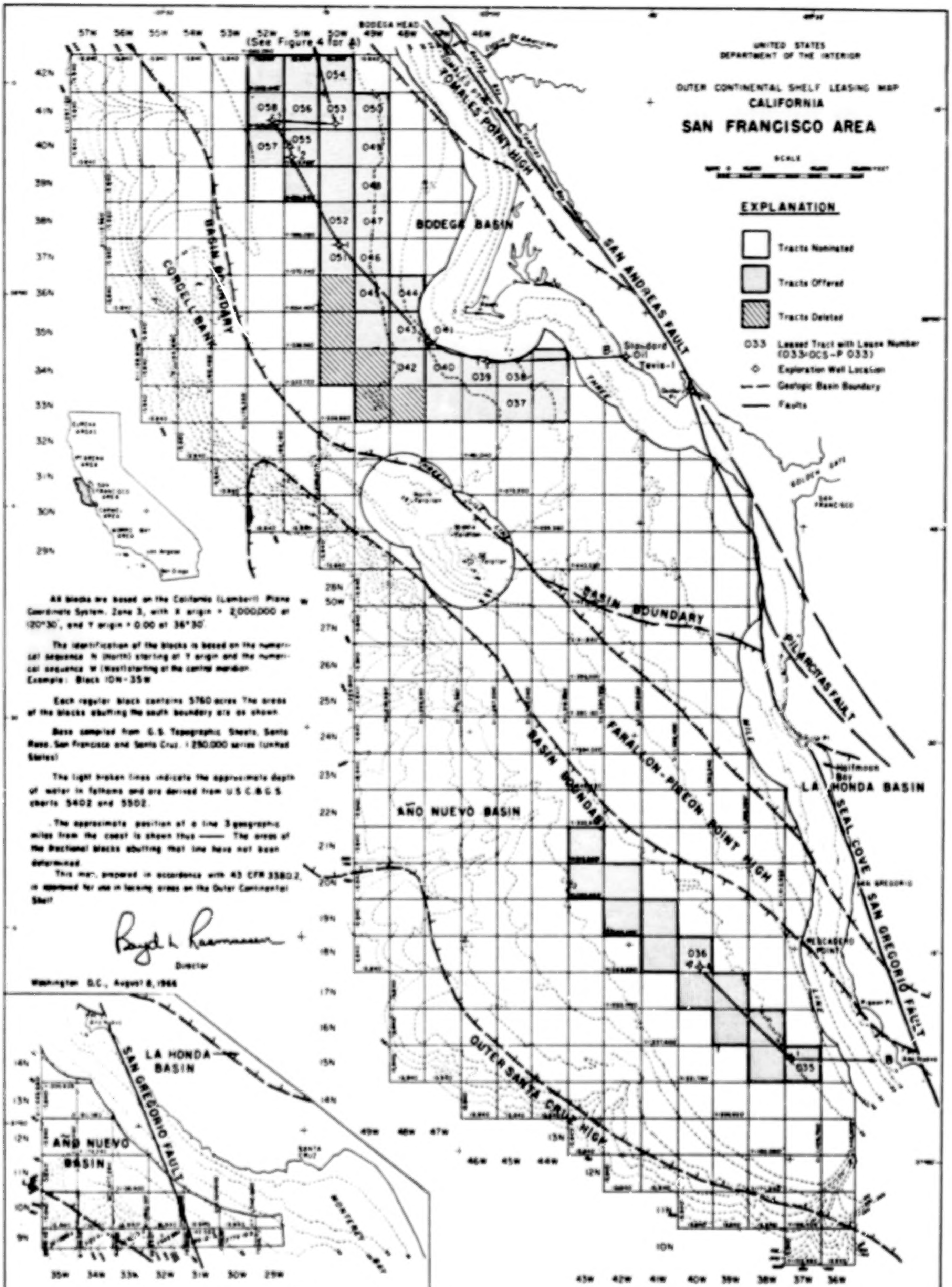

All blocks are based on the California (Lambert) Plane Coordinate System, Zone 3, with X origin = 2,000,000 at 120°30', and Y origin = 0.00 at 36°30'.

The identification of the blocks is based on the numerical sequence N (North) starting at Y origin and the numerical sequence W (West) starting at the central meridian. Example: Block 10N-35W

Each regular block contains 5760 acres. The areas of the blocks abutting the south boundary are as shown.

Base compiled from G.S. Topographic Sheets, Santa Rosa, San Francisco and Santa Cruz. 1:250,000 series (United States)

The light broken lines indicate the approximate depth of water in fathoms and are derived from U.S.C.&G.S. charts 5402 and 5502.

The approximate position of a line 3 geographic miles from the coast is shown thus ——— The areas of the fractional blocks abutting that line have not been determined.

This map, prepared in accordance with 43 CFR 3380.2, is approved for use in leasing areas on the Outer Continental Shelf.

Boyd L. Rasmussen
Director

Washington, D.C., August 8, 1966

Figure 5. San Francisco Area

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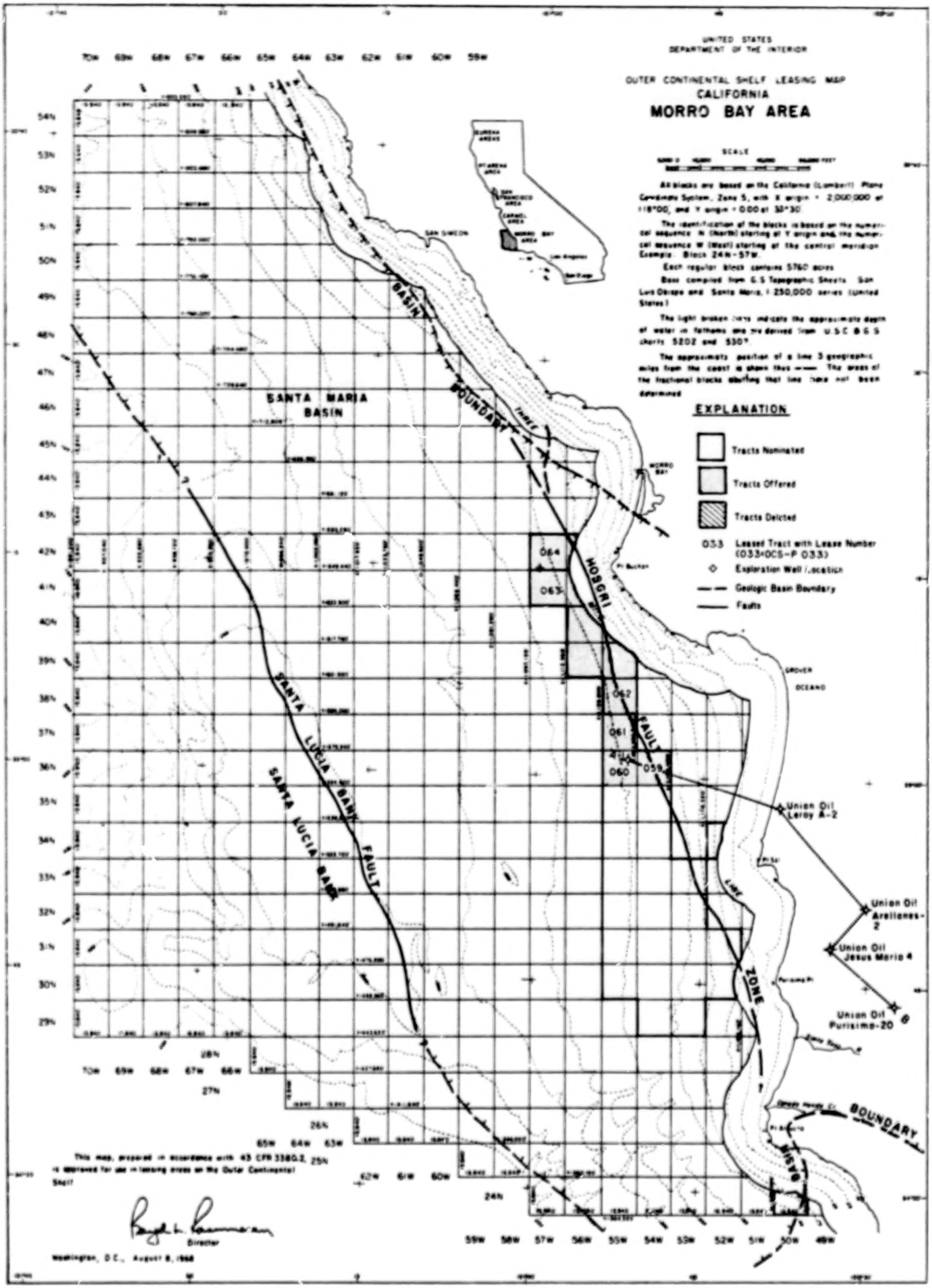
UNITED STATES
DEPARTMENT OF THE INTERIOR
OUTER CONTINENTAL SHELF LEASING MAP
CALIFORNIA
MORRO BAY AREA
SCALE
All blocks are based on the California (Lambert) Plane Coordinate System, Zone 5, with X origin = 2,000,000 at 118°00', and Y origin = 0.00 at 32°30'.
The identification of the blocks is based on the numerical sequence N (North) starting at Y origin and the numerical sequence W (West) starting at the central meridian. Example: Block 24N-57W.
Each regular block contains 5760 acres.
Base compiled from G.S. Topographic Sheets San Luis Obispo and Santa Maria, 1:250,000 series (United States).
The light broken lines indicate the approximate depth of water in fathoms and are derived from U.S.C. & G.S. charts 5202 and 5302.
The approximate position of a line 3 geographic miles from the coast is shown thus ——. The areas of the fractional blocks abutting that line have not been determined.
EXPLANATION
Tracts Nominated
Tracts Offered
Tracts Deleted
033 Leased Tract with Lease Number (033=OCS-P 033)
Exploration Well Location
Geologic Basin Boundary
Faults
SANTA MARIA BASIN
BASIN BOUNDARY
HOSGRI FAULT ZONE
SANTA LUCIA BANK FAULT
SANTA LUCIA BANK
THREE MILE LINE
SAN SIMEON
MORRO BAY
Pt Buchon
GROVER
OCEANO
Purisima Pt
064
063
062
061
060
059
Union Oil Leroy A-2
Union Oil Arellanes-2
Union Oil Jesus Maria 4
Union Oil Purisima-20
70W
69W
68W
67W
66W
65W
64W
63W
62W
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37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
27N
26N
25N
24N
This map, prepared in accordance with 43 CFR 3380.2, is approved for use in leasing areas on the Outer Continental Shelf
Director
Washington, D.C., August 8, 1968

Figure 6. Morro Bay Area

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Table 1. California Oil and Gas Lease Sale, May 14, 1963

OCS-P No.	Block No.	Bidder	Acreage	Bid Per Acre	Total Bid	Relinquished Date
Eureka Area N 1/2						
007	51N 40W	Humble Oil Superior Oil Co.	5760	$ 10.47 8.15	$ 60,307.20 46,944.00	12/14/64
008	52N 40W	Humble Oil	5760	6.97	40,147.20	12/14/64
009	47N 41W	Shell Oil Co.	5760	12.22	70,387.20	06/14/66
010	48N 41W	Shell Oil Co.	5760	13.92	80,179.20	06/14/66
011	49N 41W	Shell Oil Co.	5760	31.72	182,707.20	06/14/66
012	52N 41W	Humble Oil	5760	5.22	30,067.20	12/14/64
013	48N 42W	Shell Oil Co.	5760	12.22	70,387.20	06/14/66
014	49N 42W	Shell Oil Co.	5760	111.73	643,564.80	06/14/66
015	50N 42W	Shell Oil Co.	5760	366.57	2,111,443.20	06/14/66
016	51N 42W	Shell Oil Co.	5760	13.92	80,179.20	06/14/66
017	54N 42W	Shell Oil Co.	5760	8.85	50,976.00	06/14/66
018	48N 43W	Shell Oil Co.	5760	12.22	70,387.20	06/14/66
019	49N 43W	Shell Oil Co.	5760	28.01	161,337.60	06/14/66
020	50N 43W	Shell Oil Co.	5760	57.11	328,953.60	06/14/66
021	51N 43W	Shell Oil Co.	5760	12.22	70,387.20	06/14/66
022	55N 43W	Shell Oil Co.	5760	10.65	61,344.00	06/14/66
023	55N 44W	Shell Oil Co.	5760	10.65	61,344.00	06/14/66
Point Arena Area						
024	15N 23W	Shell Oil Co.	2237.43	$ 28.30	$ 63,335.40	06/14/67
025	16N 23W	Shell Oil Co.	5760	28.01	161,337.60	06/14/67
026	15N 24W	Shell Oil Co.	2327.42	11.76	27,377.28	06/14/67
027	16N 24W	Shell Oil Co.	5760	36.72	211,507.20	06/14/67
028	17N 24W	Shell Oil Co.	5760	11.52	66,355.20	06/14/67
029 R	34N 32W *	Donald K. Kelly	30	8.33	250.00	
030	32N 33W	Shell Oil Co.	5760	10.65	61,344.00	06/14/67
031	32N 34W	Shell Oil Co.	5760	20.20	116,352.00	06/14/67
032	33N 34W	Shell Oil Co.	5760	10.65	61,344.00	06/14/67
033	32N 35W	Shell Oil Co.	5760	44.72	257,587.20	06/14/67
034	33N 35W	Shell Oil Co.	5760	14.10	81,216.00	06/14/67

Table 1. Continuation

OCS-P No.	Block No.	Bidder	Acreage	Bid Per Acre	Total Bid	Relinquished Date
San Francisco Area						
035	15N 37W	Shell Oil Co.	5760	$ 14.10	$ 81,216.00	06/14/68
036	18N 40W	Shell Oil Co.	5760	14.10	81,216.00	06/14/68
037*	33N 45W***	Shell Oil Co.	5760	11.52	66,355.20	06/14/67
038*	34N 45W**	Shell Oil Co.	4310	12.27	52,883.70	06/14/67
039*	34N 46W**	Shell Oil Co. Humble/Std.Cal.	4320	36.72 18.17	158,630.40 78,494.40	06/14/67
040*	34N 47W**	Shell Oil Co. Humble/Std.Cal.	5450	57.11 14.43	311,249.50 78,643.50	06/14/67
041*	35N 47W**	Shell Oil Co. Humble/Std.Cal.	700	454.80 179.17	318,360.00 125,419.00	05/22/67
042*	34N 48W	Shell Oil Co.	5760	14.10	81,216.00	06/14/67
043*	35N 48W**	Shell Oil Co. Humble/Std.Cal. Superior Oil Co.	5680	416.00 70.83 8.15	2,362,880.00 402,314.40 46,292.00	05/22/67
044*	36N 48W**	Shell Oil Co. Humble/Std.Cal.	5680	11.52 10.77	65,433.60 61,173.60	06/14/67
045*	36N 49W***	Shell Oil Co.	5760	11.52	66,355.20	06/14/67
046*	37N 49W	Shell Oil Co.	5760	14.10	81,216.00	06/14/67
047*	38N 49W	Shell Oil Co.	5760	8.85	50,976.00	06/14/67
048*	39N 49W	Shell Oil Co.	5760	8.85	50,976.00	06/14/67
049*	40N 49W	Shell Oil Co.	5760	8.85	50,976.00	06/14/67
050*	41N 49W	Shell Oil Co.	5760	14.10	81,216.00	06/14/67
051*	37N 50W	Shell Oil Co.	5760	153.00	881,280.00	06/14/67
052*	38N 50W	Shell Oil Co.	5760	36.72	211,507.20	06/14/67
053*	41N 50W	Shell Oil Co. Humble/Std.Cal	5760	28.30 6.02	163,008.00 34,675.20	06/14/67
054*	42N 50W	Shell Oil Co.	5760	8.85	50,976.00	06/14/67
055*	40N 51W	Shell Oil Co.	5760	111.65	643,104.00	06/14/67
056*	41N 51W	Shell Oil Co.	5760	27.76	159,897.60	06/14/67
057*	40N 52W***	Shell Oil Co.	5760	14.10	81,216.00	06/14/67
058*	41N 52W***	Shell Oil Co.	5760	11.52	66,355.20	06/14/67

Table 1. Continuation

OCS-P No.	Block No.	Bidder	Acreage	Bid Per Acre	Total Bid	Relinquished Date
Morro Bay Area						
059	36N 54W	Humble/Std.Cal. Shell Oil Co.	5760	$ 13.93 11.52	$ 80,236.80 66,355.20	06/29/65
060	36N 55W	Humble/Std.Cal. Shell Oil Co.	5760	105.03 17.54	604,972.80 101,030.40	06/29/65
061	37N 55W	Humble/Std.Cal. Shell Oil Co.	5760	43.81 12.22	252,345.60 70,387.20	06/29/65
062	38N 55W	Humble/Std.Cal. Shell Oil Co.	5760	43.81 12.22	252,345.60 70,387.20	06/29/65
063	41N 57W	Superior Oil Co.	5760	8.15	46,944.00	06/14/67
064	42N 57W	Shell Oil Co.	5760	12.22	70,387.20	06/14/66

R - Rejected Bid

* These leases carry the stipulation concerning the Point Reyes National Seashore Area.

** All that portion lying seaward of a line 3 geographical miles distant from the coast line of California.

Total Accepted High Bids	57	$12,807,587.00
Total Amount Exposed	70	$13,989,953.00

*** No drilling or production activities will be allowed on S 1/2 OCS-P 037 and W 1/2 of OCS-P 045, W 1/2 of OCS-P 057, W 1/2 of OCS-P 058.

Table 2. Summary of California Offshore Oil and Gas Lease Sale, May 14, 1963

No. of tracts offered	129
Total acres offered	669,777
No. of tracts bid on	58
Total acres bid on	312,976
No. of tracts leased	57
Total acres leased	312,946
No. of high bids rejected	1
Total acres rejected	30
Total bonus bid	$12,807,586.68
Average bonus per acre	$40.93
Total rentals	$938,838
Total of all bids received	$13,989,702.78
High per acre bid	$454.80

bids in the sale were $2,362,880 by Shell Oil Company for lease OCS-P 043 near Point Reyes in the San Francisco area (fig. 5), and $2,111,443.20 by Shell for lease OCS-P 015 about seven miles southwest of Crescent City in the Eureka area (fig. 2). To avoid conflicts with San Francisco Bay shipping, no blocks between San Francisco and the Farallon Islands were offered for lease (fig. 5). Of the 59 blocks nominated in the Eureka area, 16 blocks (78,649 acres) opposite Arcata and Humboldt Bays were also deleted from the offering to avoid conflict with shipping (fig. 3). The latter deletion was also requested by the Department of Defense. Seventeen blocks were leased in the Eureka area, fourteen by Shell Oil Company and three by Humble Oil and Refining Company (fig. 2). In the Point Arena area, Shell Oil Company acquired all ten of the leased tracts (fig. 4). Shell won all 24 tracts leased in the San Francisco area, with the Humble/Standard consortium also bidding for six of the tracts and Superior Oil for one (fig. 5). Six tracts were leased in the Morro Bay area, four by Humble/ Standard, one by Shell, and one by Superior Oil Company (fig. 6). In the San Francisco area, all leases except the two in the Ano Nuevo basin carried stipulations regarding the Point Reyes National Seashore area. Because of shipping considerations, drilling was not allowed on portions of four leases in the Bodega basin including OCS-P 037, P 045, P 057, and P 058. All leases were relinquished by June 14, 1968, and well records were made public by the U.S. Geological Survey on December 1, 1974.

Petroleum Geology

Historically, the developed oil and gas reservoirs in coastal California were mostly porous sandstone beds, primarily of Pliocene, Miocene, Oligocene, and late Eocene age (Webster and others, 1985). A few reservoirs were in weathered and fractured basement rocks (schist and schist conglomerate) underlying the sedimentary source rocks. However, only in the onshore Santa Maria basin, most of the oil production was from reservoirs of the fractured brittle fine-grained rocks of the Monterey Formation of Miocene age (fig. 7, col. 6).

The Monterey Formation sediments were deposited within the Miocene Epoch (fig. 7), which lasted from about 25 to 5 million years before present, at a time when little mountain-building was taking place and the land surfaces were lowered by erosion almost to sea level. In early Miocene, immediately prior to the time of deposition of the Monterey Formation, a period of widespread volcanic activity occurred. This was followed by upwelling of nutrient-rich waters from deep below the surface, resulting in prolific plankton production, largely silica-shelled diatoms, but including other organisms with fatty tissues (lipids). The low onshore topography provided a source of primarily very fine-grained terrestrial rock debris which buried and preserved the organic materials in the anoxic environment of the silled basins, thus forming rich hydrocarbon source rocks. The interbedded limy silt and clay layers, silica precipitate layers, diatom- and radiolarian-rich sediments, and organic-rich clays and silts formed a heterogeneous package of hard and soft strata which in many areas constitute both the source rocks and reservoir rocks of the Monterey Formation. Deep burial of the Monterey Formation sediments by succeeding sediments over time resulted in the generation of hydrocarbons from the organic material and also caused a diagenetic change from amorphous opaline silica to cryptocrystalline silica in the silica-rich layers. The silica phase transformation released molecular water from the opaline material, causing shrinkage within the layers and creating fracture

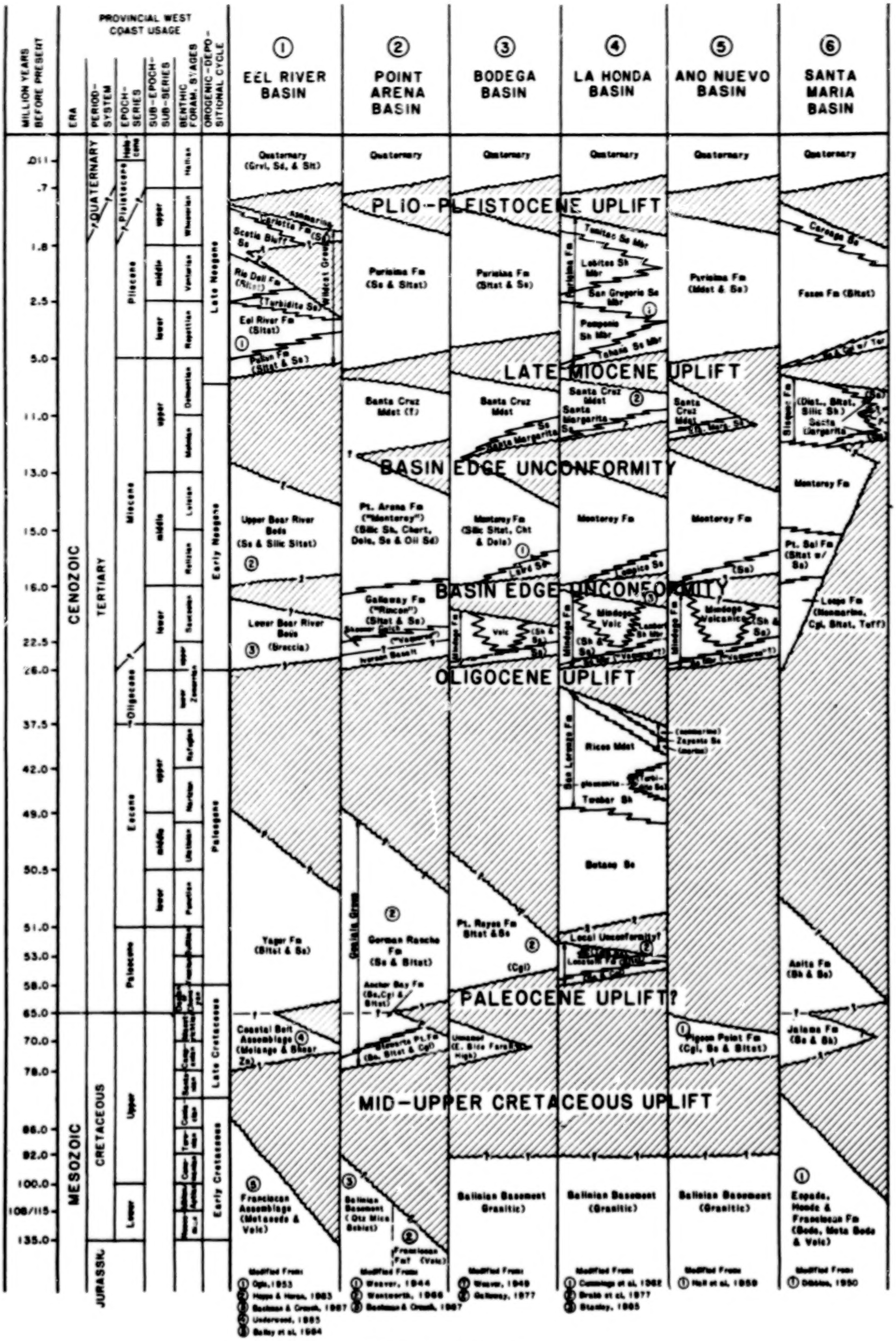

Figure 7. Stratigraphic Chart

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void spaces. Subsequent folding and faulting of the formation caused further fracturing of the brittle beds. The void spaces formed by fracturing produced reservoirs for hydrocarbons in the Monterey Formation.

Reservoir rocks of the Monterey Formation in the onshore Santa Maria basin yield an asphaltic-base, high-sulfur (sour) crude oil of low to medium API gravity (see Glossary). In the mid 1960's, Santa Maria crude sold for approximately $1 per barrel, and much of it went to Union Oil Company's refinery in Santa Maria. The heaviest fractions were processed in Union's coking plant for sale as industrial coke. Due to the heavy viscous nature of the crude, it was the established practice in the Santa Maria basin to drill wells close together so the oil in the formation had a shorter distance to travel to the well bore. These factors caused industry to conclude that fractured reservoirs could not be economically produced offshore due to the high costs of drilling, production, and transportation.

The offshore basins of central and northern California are considered to be geologic extensions of onshore basins. The Eel River basin trends northwest offshore from the Humboldt Bay area and is expected to have geologic parameters similar to those of the onshore Tompkins Hill gas field (fig. 3), where Monterey-age rocks are absent, and production is from sandstones of the post-Miocene "Wildcat Group" beds (fig. 7, col. 1). The Point Arena basin, extending north from the Mendocino/Sonoma county line to the Mendocino escarpment, is represented onshore by outcrops of Miocene beds in the vicinity of Arena Cove (fig. 4). Oil sands, within the Monterey Formation, which is locally called "Point Arena Formation," are exposed in the sea cliffs at Arena Cove. The Bodega basin extends from south of San Francisco north to the Mendocino/Sonoma County line (figs. 4 & 5). It is an extension of the oil-producing onshore La Honda (Inner Santa Cruz) basin. Miocene oil sands within the

Monterey occur in the sea cliffs at Double Point northwest of Bolinas (fig. 5). The Año Nuevo (Outer Santa Cruz) basin lies west of Pigeon Point and includes Point Ano Nuevo, onshore northwest of the town of Santa Cruz (fig. 5). At Point Ano Nuevo, the Monterey Formation, with a basal sandstone, overlies Mindego volcanics and Cretaceous-age Pigeon Point Formation.

EXPLORATION HISTORY

Hydrocarbon Use During The Pre-Drilling Era

Prior to the discovery by Drake in Pennsylvania in 1859 that wells could be drilled to tap strata saturated with oil, whale oil was extensively employed as a lubricant, for illumination, and for manufacturing. The American whaling fleet, in its peak year of 1846, numbered more than 735 vessels. The value of the whale-oil-related-businesses was over $70,000,000, and more than 70,000 persons were employed. The decline of the whaling industry after the 1850's may be ascribed primarily to the development of the American petroleum industry (Pemberton, 1943).

Tar sands, asphalt and oil seeps, tar breccias, and oil shale deposits were exploited for oil products and for road paving material prior to extensive oil well drilling. Interest in such sources was revived during World War II, resulting in geologic investigations by the Federal Government. Oil supply shortages in the middle 1950's during the Suez crisis also encouraged producing companies to investigate the potential of domestic bituminous rock and oil shale deposits. Such deposits in a geological basin generally indicate that the basin is a potential producer of petroleum. Tar sands and similar deposits are most common around the margins of oil-containing basins where the oil-rich formations are at or near the surface. They also occur within the basins where folds and faults bring these formations to the surface. Practically all of these deposits in California occur in rocks of late Miocene to early Pliocene age. They are almost always associated with richly organic upper Miocene shales (Adams and Beatty, 1962).

California coastal Indians used tar from seeps to caulk their boats, as waterproofing for basketry, as mastic for mending pottery, for joining materials, and for holding inlaid ornaments in place. Early settlers in California used products from these deposits as lubricants, for medical purposes, and later, to refine for illuminating oil. Pits, trenches, and extensive tunnels were used to collect liquid petroleum.

In the 1880's, bituminous rock was mined at various locations, including sites north of Santa Cruz in Santa Cruz County and at Edna in San Luis Obispo County. Total production of tar sands used for paving materials for the year 1887 was 36,000 tons. In 1892, five quarries were operating in Santa Cruz County. These and quarries in Santa Barbara and San Luis Obispo Counties were the principal sources of asphalt rock for the next 30 years, with peak production of 87,000 tons in 1910. Mine-run rock ranged up to $6 per ton and was shipped to San Francisco and Los Angeles (Adams and Beatty, 1962). The general locations of these deposits are shown in figure 8.

In addition, small primitive illuminating oil refineries, located at seepages, were in operation in the 1850's. A refinery was operating at Point Arena in about the year 1864 using tar sand as raw material, and one was established in San Francisco to refine illuminating oil from oil obtained from pits and shallow wells at Petrolia in Humboldt County. A separation plant at Sisquoc in Santa Barbara County shipped oil by pipeline to Gaviota from 1895 to 1905.

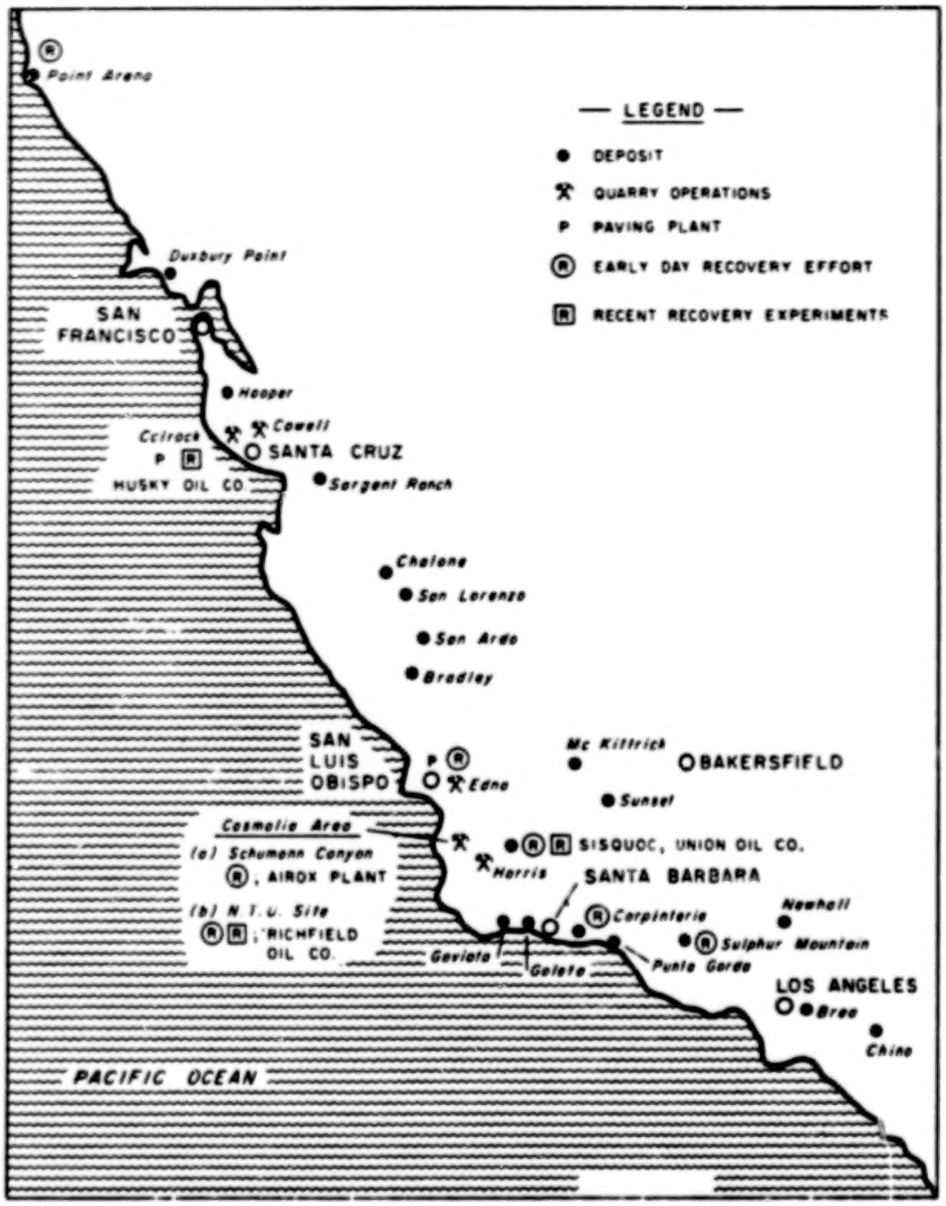

Figure 8. Bituminous Rock Deposits and Operations in California (after Adams and Beatty, 1962).

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Onshore Drilling History

Eel River Basin

The first commercial production of petroleum in California and the first commercial sale of oil refined in the State occurred during the years 1864-1865. The oil came from the Mattole River area in Humboldt County adjacent on the south to the Eel River basin (Webster and others, 1986). It was an area of numerous oil and gas seeps. Production was from highly deformed Paleogene and Cretaceous sediments. In the following 85 years, more than 50 wells were drilled in the general area. Some were temporary producers of light oil, some of gas. Most were located near seeps (Ogle, 1953). In October 1953, the Petrolia oil field was discovered near the older area and produced oil of 46° API gravity. Two wells were completed, but the field was abandoned in September 1971 after producing a total of only 350 barrels of oil (California Division of Oil and Gas, 1981).

In September 1937, the Texas Co. (now Texaco, Inc.) drilled the discovery well of the Tompkins Hill gas field in the Eel River basin onshore (fig. 3). On December 31, 1985, there were 36 producing wells, and cumulative production from the field was 86.615 Bcf (billion cubic feet) of gas with 9.041 Bcf remaining reserves. The Tompkins Hill gas field is not considered a major gas field since fields with gas reserves of 300 Bcf are considered to be major.

The Table Bluff gas field was discovered in June 1960 and abandoned in December 1968. Cumulative production was 109 MMcf (million cubic feet) (California Division of Oil and Gas, 1986). Other potential discoveries were never connected to a pipeline and therefore were not put on production. Eel River basin gas production is from thin sandstones beds in the Rio Dell Formation of Pliocene age (Ogle, 1953).

Point Arena Basin

The earliest well on record in the Point Arena area onshore was drilled to 780 feet in 1918, and at least four additional wells were drilled prior to 1964. One of them tested 43° API gravity oil at a rate of 8 B/D (barrels per day) before it was abandoned. Another tested Eocene gas at 10 Mcf/D (thousand cubic feet per day) rate. Tar and heavy oil shows were found in the Miocene section of all the wells, and shows of high-gravity oil were noted in the pre-Miocene section of most wells (California Division of Oil and Gas 1982; Weaver, 1943).

Bodega Basin

Although no commercial production has been established in the Point Reyes area, abundant shows of oil are present in beach outcrops north of Duxbury Point. Active seeps of both oil and gas have been reported also. The seeps attracted oil well drilling in the area as early as 1865. At least fourteen wells were drilled, ranging in depth from 80 feet to 8,409 feet. The last well was abandoned in 1954. None of the wells were commercial successes, although one is reported to have produced a few barrels of heavy oil for a short time from the Monterey Formation (Galloway, 1977).

La Honda Basin (Inner Santa Cruz Basin)

Seepages of high-gravity oil and gas from Miocene and Pliocene sediments and shows of oil in shallow water wells have encouraged oil well drilling in the Halfmoon Bay area since 1867. Wells producing from 25 to as much as 200 barrels daily of high gravity oil from Miocene and Pliocene reservoirs have been drilled in the area. The oil was refined locally for its high gasoline content (Crandall, 1943).

The Moody Gulch oil field, located just west of the San Andreas fault in the eastern part of the La Honda basin, was first drilled in 1880. The field produced high gravity oil from a 10-acre area. Most of the drilling was prior to 1912, and total production was in excess of 85,000 barrels by 1921. Little has been produced since, and a major highway now covers the field. Production was from thin sands within the Eocene-Oligocene age San Lorenzo Formation (Kreuger, 1943).

La Honda oil field in the Santa Cruz Mountains of San Mateo County was discovered in 1956. Production of 90 to 750 B/D of 32.8° API gravity oil was from the Butano Formation of late Eocene age (Fothergill, 1962). Additional production of 24° oil was found in basal Purisima sands of Pliocene age in 1958 (California Division of Oil and Gas, 1981). Cumulative production through December 1985 was 1,316,000 barrels (California Division of Oil and Gas, 1986). The Oil Creek oil field was discovered in 1955, also producing from upper Eocene sands. Total production to December 1985 was 192,000 barrels of 43.2° oil (Fothergill, 1962; California Division of Oil and Gas, 1981; 1986).

Ano Nuevo Basin (Outer Santa Cruz Basin)

The basin includes the outcrop of Monterey Formation at Point Ano Nuevo, and possibly extends southeastward to surround Monterey Bay, but the onshore extension of the Ano Nuevo basin east of the San Gregorio-Palo Colorado fault zone is questionable. Two wells were drilled onshore west of the fault. Each penetrated post-Miocene sediments overlying Pigeon Point Formation of Late Cretaceous age. East of the San Gregorio - Palo Colorado fault, the onshore area adjoining Monterey Bay on the north and east has seen much wildcat drilling beginning in 1922, and culminating in the 1950's. Upper Miocene and Pliocene sediments overlie granitic basement rocks in the area. No production has been established, although a well drilled to 7,916 feet in 1946 had good shows of oil. At 3,040 feet, this well penetrated conglomerates filling an ancient landward extension of the Monterey submarine canyon cut into the granite. The Salinas basin, extending southeastward from the city of Monterey, may be more closely related to the Ano Nuevo basin.

Santa Maria Basin

The onshore Santa Maria basin is one of the oldest producing regions in California. The oldest oil field, Orcutt, was discovered in 1902. The Santa Maria basin is also one of the most productive regions relative to the volume of sediments. The basin is small in area and the section varies in thickness, averaging less that 7,000 feet. Fifteen fields had produced a cumulative 786,022,000 barrels of oil at the end of December 1985 (Conservation Committee of California Oil Producers, 1986).

Offshore Drilling History

Drilling in the Pacific OCS on leases obtained in the May 14, 1963 sale began September 20, 1963 in the Point Reyes area northwest of San Francisco on lease OCS-P 041. This was the first of 20 exploratory wells to be drilled from 19 locations on 17 leases (table 3). Drilling continued through September 1967, with the last well located in the Pigeon Point area northwest of Santa Cruz on lease OCS-P 035. Two wells were drilled from the drillship CUSS I; two from the drillship Glomar II; one from the drillship WODECO III; and the rest from the semi-submersible vessel Bluewater II. Total depths of the wells ranged from 897 feet to 10,636 feet, and water depth ranged from 200 feet to 574 feet. Well depths are measured from the rotary table (RT)(Table 3).

Although weather interrupted operations on some of the wells drilled

TABLE 3. OCS EXPLORATORY WELLS

Northern and Central California

Operator	Lease	Well No.	A. P. I. No.	Location Lat./Long.	Vessel	Spud Date	Completion Date	Water Depth feet	Total Depth feet	RT Elev. feet
Humble	P-007	1	56-092-00003	41° 31.6' 124°18.0'	CUSS I	07-12-64	07-27-64	250	897	27
Humble	P-012	1	56-092-00004	41° 32.3' 124°21.4'	CUSS I	07-30-64	08-08-64	298	2964	27
Shell	P-014	1	56-092-00002	41° 26.1' 124°25.4'	Bluewater II	06-17-65	07-07-65	393	7377	67
Shell	P-019	1	56-092-00001	41° 24.9' 124°28.1'	Bluewater II	07-11-65	07-30-65	574	7779	67
Shell	P-027	1	56-069-00004	38° 20.5' 123°17.2'	Bluewater II	11-17-64	11-29-64	348	3234	70
Shell	P-030	1	56-070-00003	39° 00.9' 123°49.2'	Bluewater II	03-10-65	06-09-65	312	10636	69
Shell	P-032	1	56-070-00001	39° 04.5' 123°53.1'	Bluewater II	11-25-66	01-13-67	389	9609	68
Shell	P-033	1	56-070-00002	39° 01.7' 123°54.5'	Bluewater II	10-24-66	11-10-66	414	4719	69
Shell	P-035	1	56-068-00001	37° 06.8' 122°29.9'	Bluewater II	09-01-67	09-29-67	328	7736	68
Shell	P-036	1	56-068-00002	37° 14.1' 122°38.9'	Bluewater II	02-11-67	03-17-67	324	9490	68
Shell	P-039	1	56-068-00003	37° 56.3' 122°59.1'	Bluewater II	02-16-65	03-03-65	200	5632	69
Shell	P-041	1	56-068-00005	37° 57.7' 123°04.9'	Glomar II	09-20-63	12-13-63	250	4700	30
Shell	P-051	1	56-069-00006	38° 04.3' 123°13.6'	Glomar II	12-22-63	01-10-64	368	1170	30
Shell	P-051	2	56-069-00007	38° 04.3' 123°13.6'	Bluewater II	08-02-64	10-03-64	363	10466	70
Shell	P-053	1	56-069-00008	38° 12.9' 123°14.6'	Bluewater II	12-02-64	12-26-64	346	8059	70
Shell	P-055	1	56-069-00009	38° 11.4' 123°18.1'	Bluewater II	10-12-64	11-06-64	414	7477	68
Shell	P-055	2	56-069-00010	38° 10.4' 123°18.0'	Bluewater II	01-03-65	01-23-65	421	7261	68
Shell	P-055	2 A	56-069-00011	38° 10.4' 123°18.0'	Bluewater II	01-24-65	02-03-65	421	7297	68
Shell	P-058	1	56-069-00012	38° 12.9' 123°19.7'	Bluewater II	01-18-67	02-05-67	440	7881	68
Standard of Calif	P-060	Oceano 1	56-046-20001	35° 1.2' 120°52.5'	WODECO III	09-29-64	01-07-65	550	8020	34
TOTAL		20								

from drillships, it did not delay those drilled from semi-submersible vessels. As no excessive mud weights were used, no abnormal formation pressures were indicated. Mud weight gradients were only 65-70 percent of fracture gradients (Zieglar and Cassell, 1978).

Eel River Basin

In the offshore Eel River basin (figs. 2 & 3), four exploratory test wells were drilled during the one-year period from July 12, 1964, to July 11, 1965 (table 3). There were no shows of hydrocarbons in any of the wells.

Two of the wells were drilled by Humble Oil and Refining Company from the CUSS I. Humble's OCS-P 007 No. 1 well was spudded (started drilling) July 12, 1964, at a water depth of 250 feet in Quaternary sediments which were penetrated by the drill until basement rocks of the Franciscan assemblage were encountered at 685 feet. Total depth of the well was 897 feet (fig. 9, fig. 7, col. 1). Humble's OCS-P 012 No. well 1, which was drilled about three miles northwest of OCS-P 007 No. 1 in 298 feet of water, was also on a basement high. It was spudded on July 30, 1964, and was drilled through Quaternary sediments until basement rocks were encountered at 2,920 feet. The well bottomed at a depth of 2,964 feet on August 8, 1964, without encountering the "Wildcat Group" sediments from which gas is produced onshore.

The following year, Shell Oil Company drilled two wells during the period from June 17, 1965 to July 30, 1965, using the Bluewater II. OCS-P 014 No. 1 was drilled nine miles southwest of OCS-P 007 No. 1 in 393 feet of water and penetrated "Wildcat Group" sediments from 2,980 feet to 6,050 feet with no shows of hydrocarbons. Total depth was reached at 7,377 feet in the Yager formstion of pre-Miocene age(fig. 9). OCS-P 019 No. 1 was drilled from July 11, 1965 to July 30, 1965, in 574 feet of water three miles west of OCS-P 014

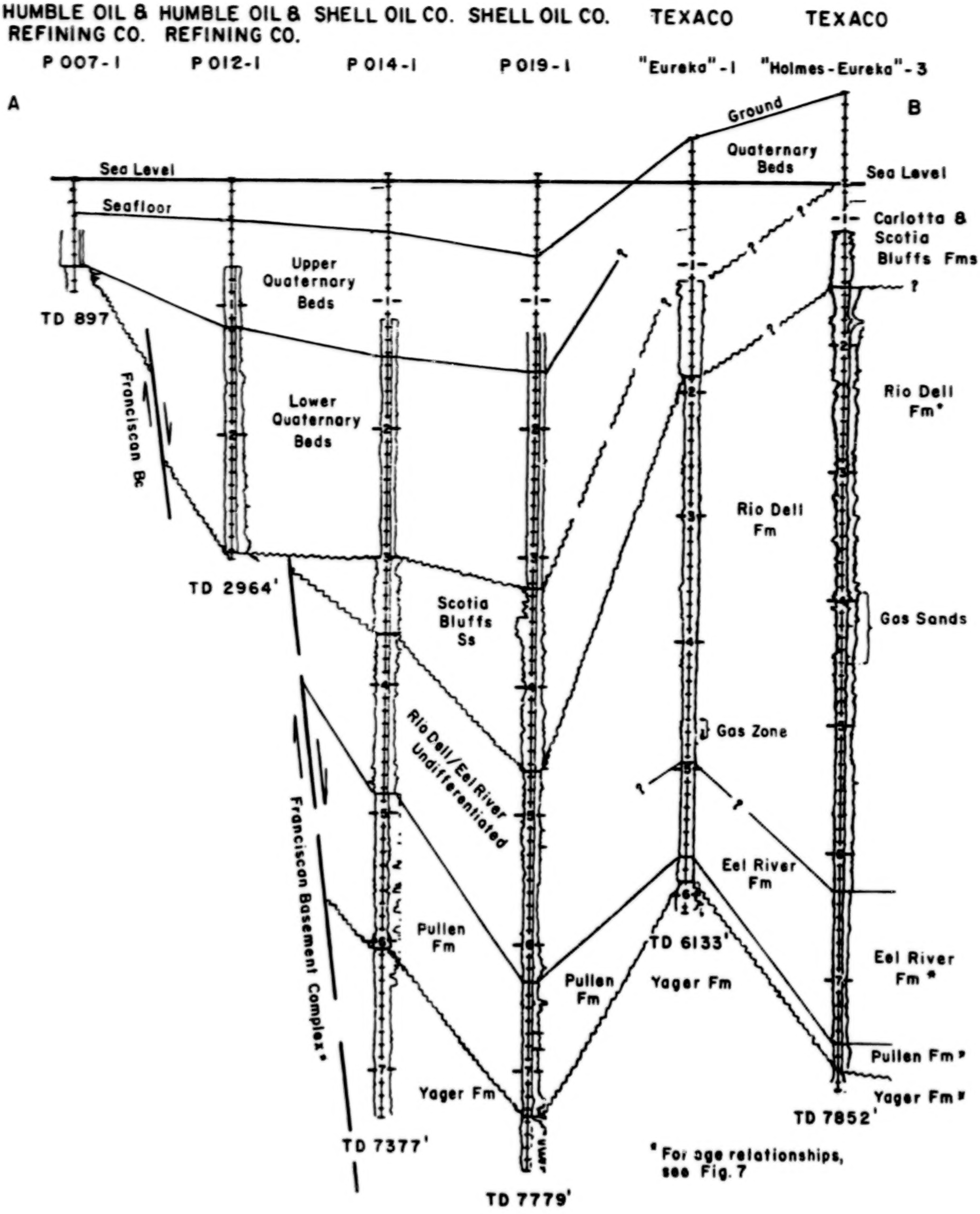

Figure 9. Correlation Chart - Eel River Basin Wells. (See figures 2 and 3 for locations of wells).

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No. 1. It penetrated the "Wildcat Group" sediments from 3,230 feet to 7,380 feet and bottomed in the Yager Formation at 7,779 feet (fig. 9). No hydrocarbon shows were encountered, and no formation tests were run.

Point Arena Basin

Three wells were drilled in the Point Arena basin by Shell Oil Company from the Bluewater II (table 3; fig. 4). OCS-P 030 No. 1 was spudded in 312 feet of water about six miles northwest of Point Arena on March 10, 1965, and abandoned on June 9, 1965, at 10,636 feet total depth. The well was drilled on a faulted and tightly folded structure. It penetrated a sedimentary section composed of Pliocene and late Miocene beds of the Santa Cruz Mudstone to a depth of 2,270 feet, and below, steeply dipping beds of Miocene siliceous shale, limy shale, and siltstone were penetrated to total depth. These sediments included the Point Arena and Gallaway Formations which are similar in age and lithology to the Monterey and Rincon Formations (fig. 10; fig. 7, col. 2). From the first drill cuttings recovered, at 561 feet depth, to total depth, up to 90 percent of the cuttings were coated with free, tarry oil. Six wireline formation tests were made with all but one recovering some fluid, mostly water. Formation Test No. 1, in the Point Arena Formation at 5,130 feet, recovered 50 cc of oil with API gravity of 29°, and 9,950 cc of water.

OCS-P 033 No. 1, drilled about 5.5 miles west of OCS-P 030 No. 1, was spudded in 414 feet of water on October 24, 1966, and abandoned on November 10, 1966, at 4,719 feet total depth in metamorphic basement rock (fig. 10). It penetrated post-Miocene (Purisima?) beds to 1,530 feet, Miocene (Point Arena, Gallaway and Skooner Gulch Formations) to 3,860 feet, pre-Miocene German Rancho and Gualala sediments to 4,550 feet. Weak oil shows were noted

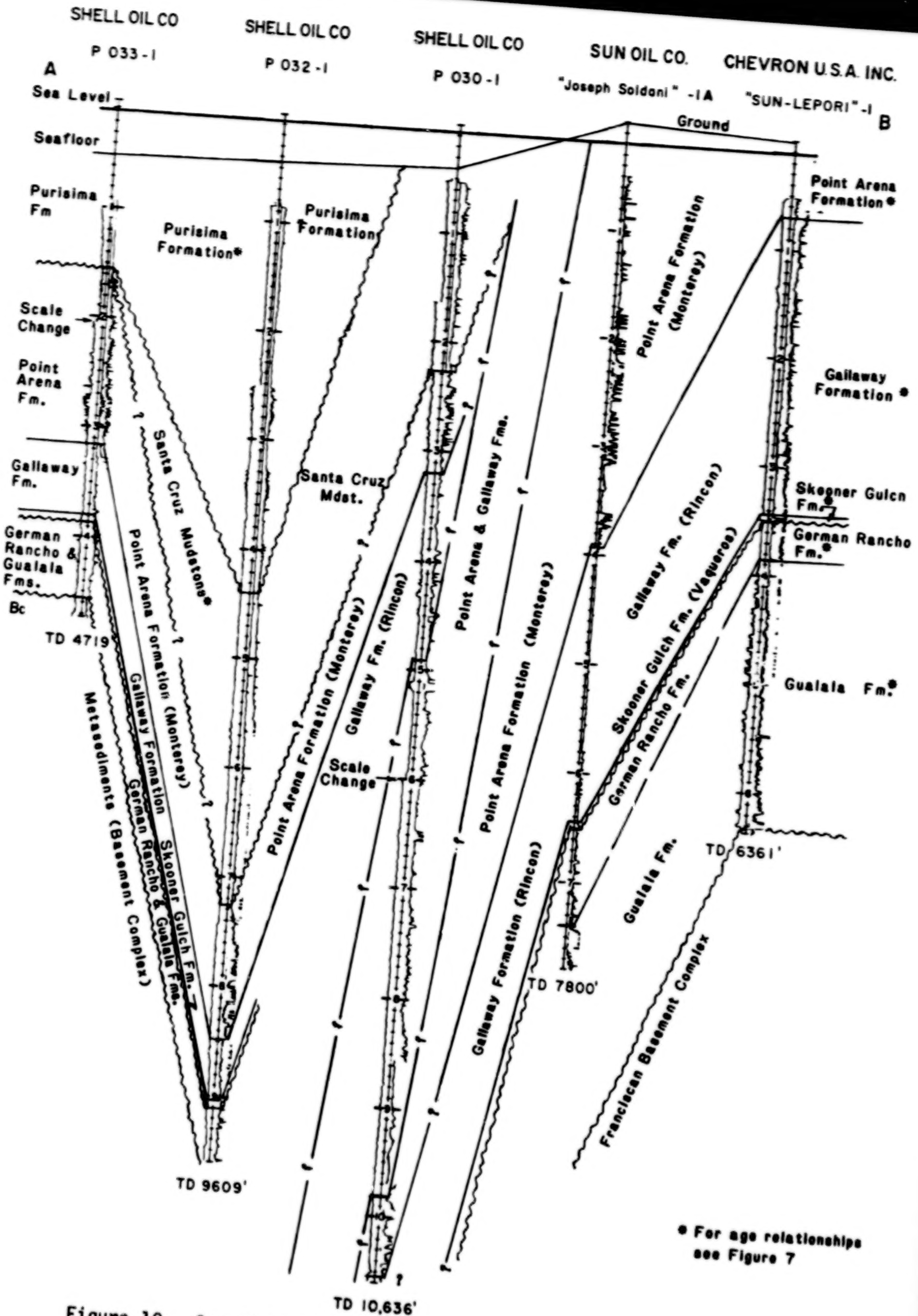

Figure 10. Correlation Chart - Point Arena Basin Wells. (See figure 4 for locations of wells).

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in the Point Arena Formation and in the basal Miocene Skooner Gulch (Vaqueros) sand.

Well OCS-P 032 No. 1 was drilled about four miles northeast of OCS-P 033 No. 1. It was spudded on November 25, 1966, in 389 feet of water and was abandoned on January 13, 1967, at 9,609 feet total depth in pre-Miocene German Rancho Formation (fig. 10). The well penetrated Purisima Formation to about 4,400 feet and Santa Cruz Mudstone to about 7,200 feet. Miocene Point Arena, Gallaway, and Skooner Gulch Formations were drilled from 7,200 to 9,100 feet. Weak oil shows occurred throughout the Point Arena Formation and a few shows were logged below it. There were no formation tests made in any wells except OCS-P 030 No. 1.

Bodega Basin

Ten exploration wells were drilled in the Bodega basin (figs. 4 and 5) all by Shell Oil Company. The first exploratory well drilled in the Pacific OCS was OCS-P 041 No. 1, about 3.5 miles southwest of Point Reyes in 250 feet of water (table 3). Drilling commenced on September 20, 1963, using the CUSS I, but was stopped by rough weather on October 8 at 4,401 feet depth. The hole was re-entered on December 3, 1963, using the Glomar II. Santa Cruz Mudstone was penetrated to 1,282 feet, Monterey and Laird Formations to 2,312 feet, Mindego Formation to 2,440, and Point Reyes Formation to 4,475 feet, where the drill encountered granitic basement rocks (fig. 11; fig. 7, col. 3). The well was abandoned on December 13, 1963, at 4,700 feet total depth. Traces of oil staining were observed only in the Miocene rocks below the Monterey Formation, and in the Point Reyes Formation of Paleocene age.

Next, OCS-P 051 No. 1 was drilled from the Glomar II about 12 miles to the northwest. The well was spudded on December 22, 1963, in 368 feet of water. After drilling to 1,170 feet, rough weather forced abandonment of the hole on January 10, 1964. No drill cuttings were recovered and no logs were run. All subsequent wells in the basin were drilled from the Bluewater II. OCS-P 051 No. 2 was drilled about 65 feet southeast of the No. 1 location. It was spudded on August 2, 1964, in 363 feet of water and was abandoned on October 3, 1963, at 10,466 feet total depth (fig. 11 cont'd). The base of Quaternary sediments was 650 feet, and sediments of the Purisima Formation were drilled to a depth of about 1,890 feet. Santa Cruz Mudstone was drilled to 5,272 feet, Monterey Formation to 6,230 feet, Laird Sandstone to 6,330 feet, and Point Reyes Formation to total depth. No shows of hydrocarbons were noted.

OCS-P 055 No. 1 was drilled about 9.5 miles northwest of OCS-P 051 No. 2. Drilling commenced on October 12, 1964, in 414 feet of water, and the well was abandoned November 6, 1964, at 7,477 feet total depth (fig. 11). The hole penetrated Quaternary beds to 737 feet, Purisima Formation to 2,860 feet, Santa Cruz Mudstone to 5,915 feet, Monterey Formation to 6,138 feet, Laird Sandstone to 6,160 feet, Mindego Formation to 6,303 feet, and Point Reyes Formation to total depth. About 50 feet of Laird Sandstone and Mindego Formation contained thin beds of oil-stained sand.

Next, OCS-P 027 No. 1 was drilled east of the Point Reyes fault about 30 miles northwest of Point Reyes. Drilling commenced on November 17, 1964, in 348 feet of water, and was abandoned on November 29, 1964, at 3,234 feet total depth (fig. 11). It penetrated Quaternary sediments to 742 feet, Monterey formation to 1,308 feet, Laird Sandstone to 1,472 feet, Mindego Formation to 1,872 feet, and Point Reyes Formation to total depth. Shows of tar occurred throughout the Monterey, Laird, and Mindego Formations, with some dead oil in the upper intervals. A weak show was also noted in the Point Reyes Formation. A drill stem test (DST) was run in sands in the upper part of the Mindego

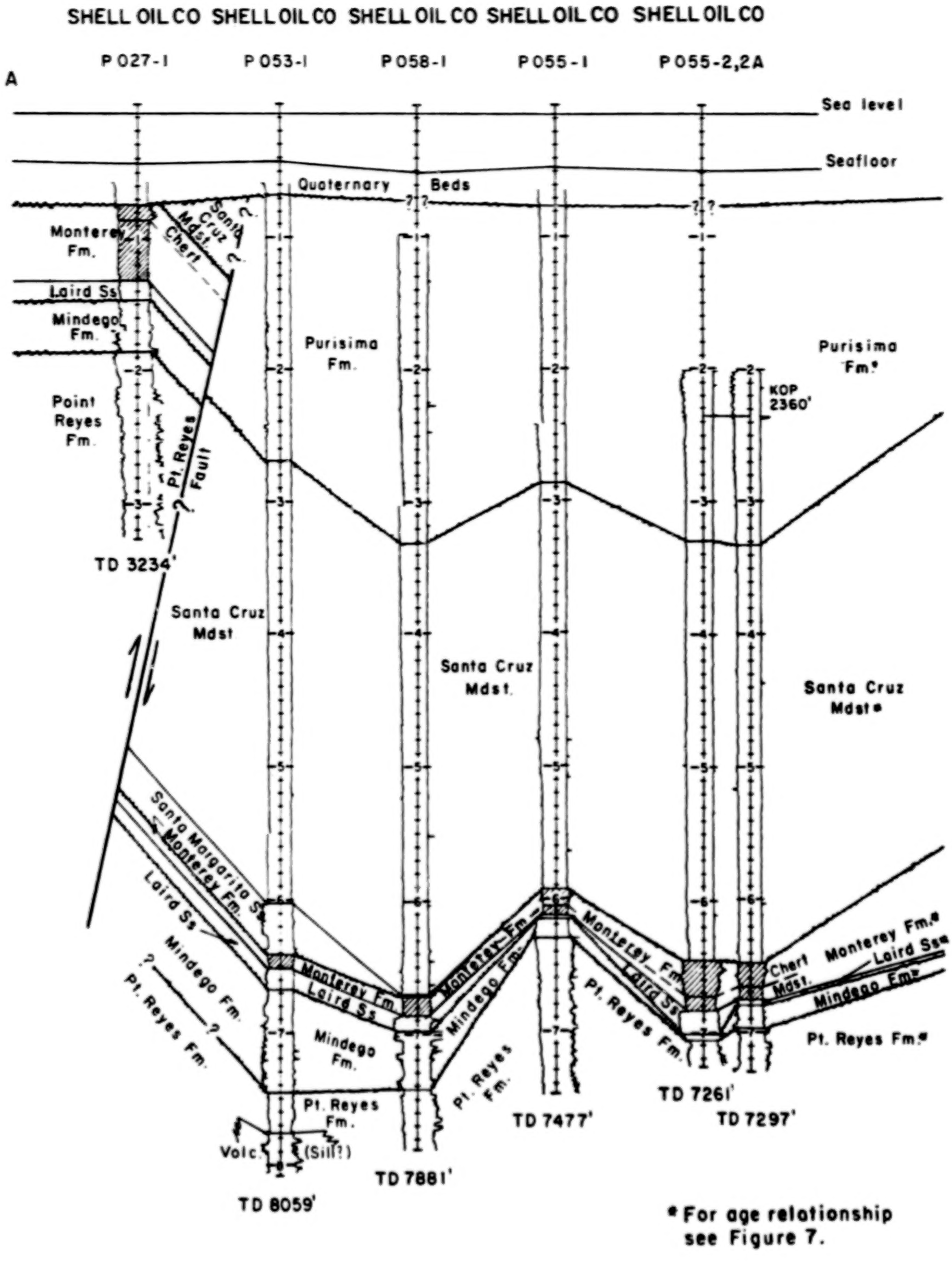

Figure 11. Correlation Chart - Bodega Basin Wells.

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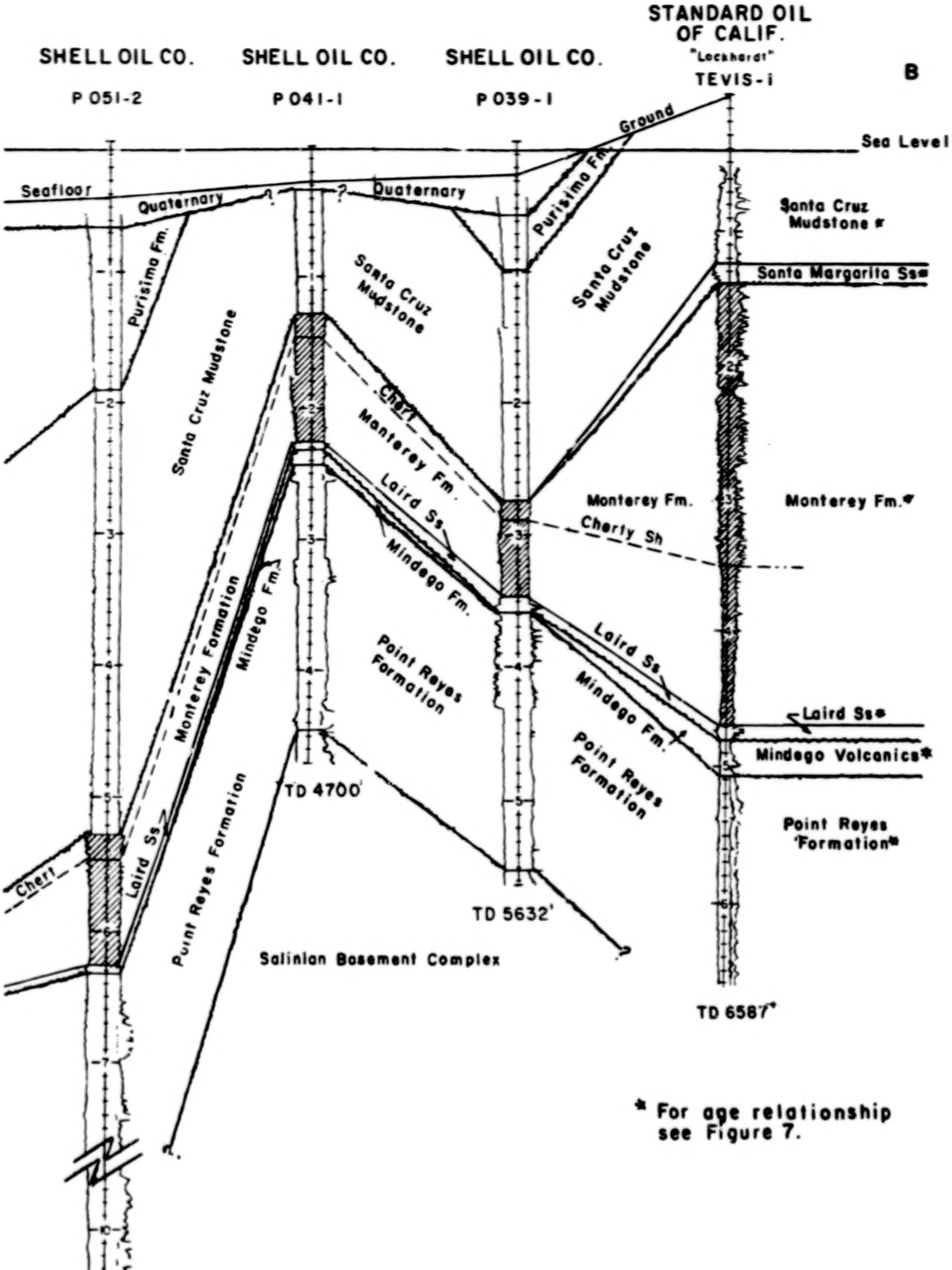

Figure 11. Correlation Chart-Bodega Basin Wells -- Continued (See figures 4 and 5 for locations of wells)

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Formation, but only drilling mud and water were recovered. No other formation tests were run in wells in the Bodega basin.

OCS-P 053 No. 1 well was then spudded about 4.5 miles northeast of OCS-P 055 No. 1, in 346 feet of water on December 2, 1964. The well was abandoned December 26, 1964, at total depth of 8,059 feet in volcanics, possibly in a dike or sill (fig. 11). Quaternary sediments were drilled to 675 feet, Purisima Formation to 2,682 feet, Santa Cruz Mudstone to 6,035 feet, Santa Margarita Sandstone to 6,395 feet, Monterey Formation to 6,537 feet, Laird Sandstone to 6,660 feet, Mindego Formation to 7,450 feet, and Point Reyes Formation to 7,770 feet where volcanics were encountered. Chert was absent in the Monterey. No hydrocarbon shows were noted.

Shell returned to lease OCS-P 055 to drill No. 2 about 1.5 miles south of No. 1. Drilling commenced on January 3, 1965, in 421 feet water depth and was abandoned on January 23, 1965, at 7,261 feet total depth in Point Reyes Formation (fig. 11). The Purisima/Santa Cruz contact was at 3,295 feet, top of Monterey at 6,450 feet, top of Laird at 6,822 feet, Mindego at 7,000 feet, and Point Reyes Formation at 7,060 feet. Oil stains and traces of bleeding oil were noted from 6,480 to 6,590 feet in Monterey chert, and oil fluorescence was noted from 6,700 to 6,745 feet in shales of the Monterey Formation. The top of the first electric log (E-log) run was at 2,020 feet.

On January 24, 1965, the hole was redrilled as OCS-P 055 No. 2A. Kickoff point for the new hole was at 2,360 feet, and top of the first E-log was at 2,026 feet. The hole was directed northwesterly from the surface location by turbo-drill and drilled to 7,297 feet before it was abandoned in Point Reyes Formation on February 3, 1965, (fig. 11). The section penetrated was Purisima to 3,317 feet, Santa Cruz to 6,477 feet, Monterey to 6,742 feet, Laird to 6,778 feet, Mindego to 6,970 feet and Point Reyes to total depth.

Oil staining, odor, fluorescence, and some bleeding oil were noted in chert of the Monterey Formation from 6,490 to 6,650 feet.

The drilling vessel was then moved back to Point Reyes to spud OCS-P 039 No. 1, 3.5 miles due south of the point, on February 16, 1965 (fig. 11 cont'd). The well spudded in Quaternary sediments and penetrated Purisima Formation from 532 feet to 990 feet, Santa Cruz Mudstone to 2,730 feet, Monterey Formation to 3,470 feet, Laird Sandstone to 3,560 feet, and Point Reyes Formation to 5,535 feet, where the drill encountered granitic basement rocks. The hole was abandoned at 5,632 feet on March 3, 1965. No hydrocarbon shows were noted.

OCS-P 058 No. 1, about 2.5 miles northwest of OCS-P 055 No. 1, was spudded on January 18, 1967, in 440 feet of water. The well was abandoned February 5, 1967, at 7,881 feet (fig. 11). It spudded in Quaternary sediments at 508 feet and penetrated Purisima Formation from about 750 feet to 3,317 feet. Santa Cruz Mudstone was drilled to 6,710 feet with Santa Margarita Sandstone to 6,728 feet. Monterey Formation, with the chert member missing, was found from 6,728 to 6,872 feet, Laird Sandstone to 6,992 feet, Mindego sediments and volcanics to 7,430 feet and Point Reyes Formation to total depth. Oil stains and hydrocarbon fluorescence were noted from 6,700 to 6,800 feet in the Monterey Formation. A total of ten wells, from nine locations, were drilled in the Bodega basin.

La Honda (Inner Santa Cruz) Basin

No wells were drilled in offshore La Honda basin (fig. 5; fig. 7, col. 4).

Ano Nuevo (Outer Santa Cruz) Basin

The last two wells drilled on leases obtained in the 1963 offering were located in the Ano Nuevo basin (Outer Santa Cruz basin of Hoskins and

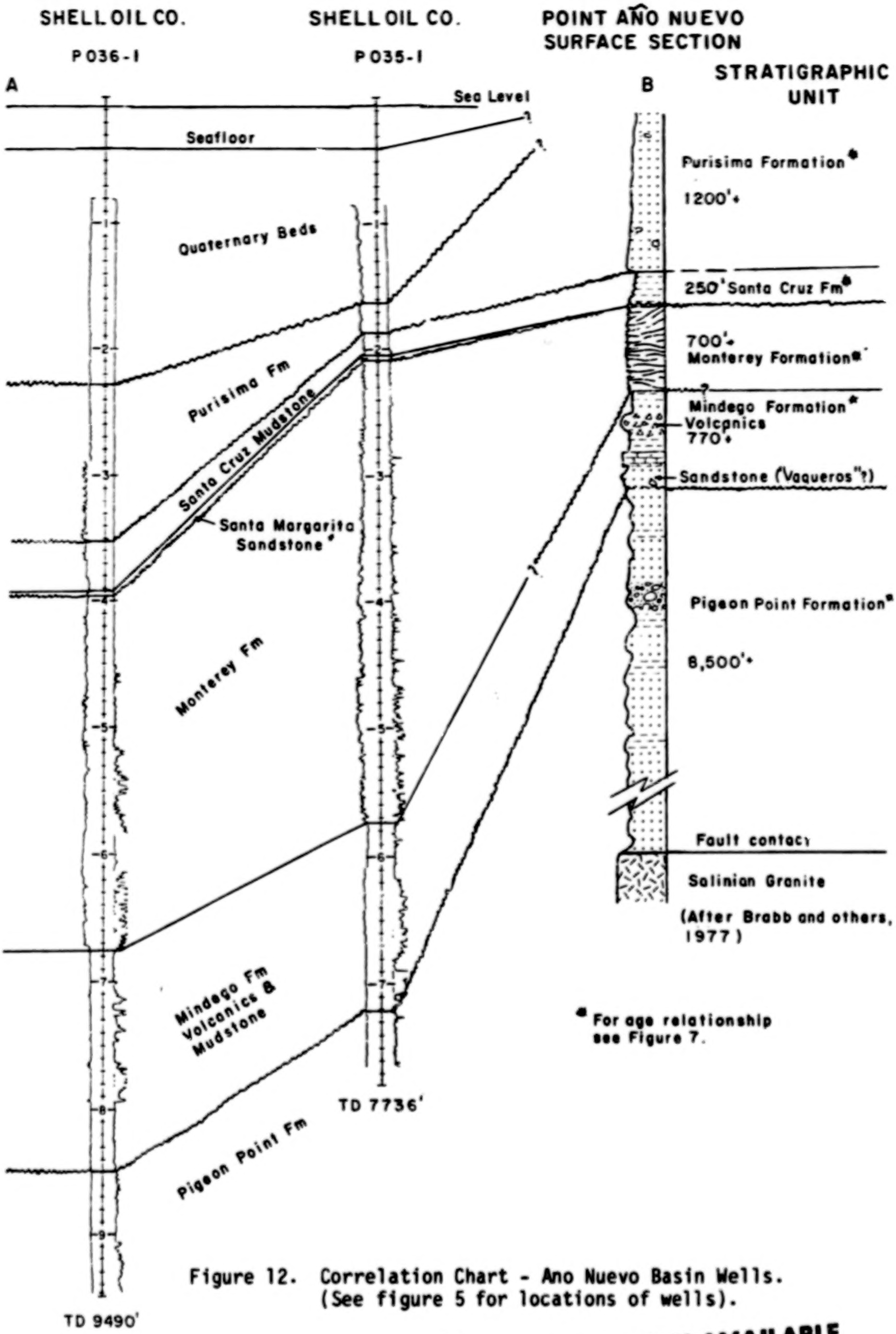

Figure 12. Correlation Chart - Ano Nuevo Basin Wells. (See figure 5 for locations of wells).

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Griffiths, 1971) (table 3; fig. 5). Both were drilled by Shell Oil Company from Bluewater II. OCS-P 036 No. 1, located about 13 miles west of Pigeon Point, was spudded in 324 feet of water on February 11, 1967 (fig. 12; fig. 7, col. 5). It was abandoned at a total depth of 9,490 feet on March 17, 1967. The drill penetrated Quaternary beds to 2,270 feet, Purisima Formation to 3,520 feet, Santa Cruz Mudstone to 3,940 feet, sandstone of the Santa Margarita Sandstone to 3,970 feet, Monterey Formation to 6,760 feet, Mindego Formation to 8,500 feet, and Pigeon Point Formation of Late Cretaceous age to total depth. Drill cuttings throughout the Monterey Formation were coated (up to 100 percent) with free tarry oil, and oil shows were noted in the Mindego Formation.

OCS-P 035 No. 1, located about 11.5 miles southeast of OCS-P 036 No. 1, was spudded on September 1, 1967, in 328 feet of water and was drilling in Pigeon Point Formation when it reached total depth at 7,736 feet (fig. 12). Quaternary beds were penetrated to about 1,630 feet, Purisima Formation to 1,875 feet, Santa Cruz Mudstone to 2,015 feet, Santa Margarita to 2,080 feet, Monterey Formation to 5,730 feet, and Mindego Formation to 7,210 feet. Although free tarry oil coated the drill cuttings throughout the Monterey Formation, there was somewhat less than observed in OCS-P 036. No formation tests were run on either well. The well was abandoned on September 29, 1967.

Santa Maria Basin

The only well drilled in the Santa Maria basin on leases from the 1963 lease offering was Standard Oil Company of California's Standard-Humble OCS-P 060 "Oceano" No. 1 (table 3; fig. 6). This well is located on presently active lease OCS-P 0396 issued as a result of Sale No. 53 of May 28, 1981. The well was spudded on September 29, 1964, from the drillship WODECO III,

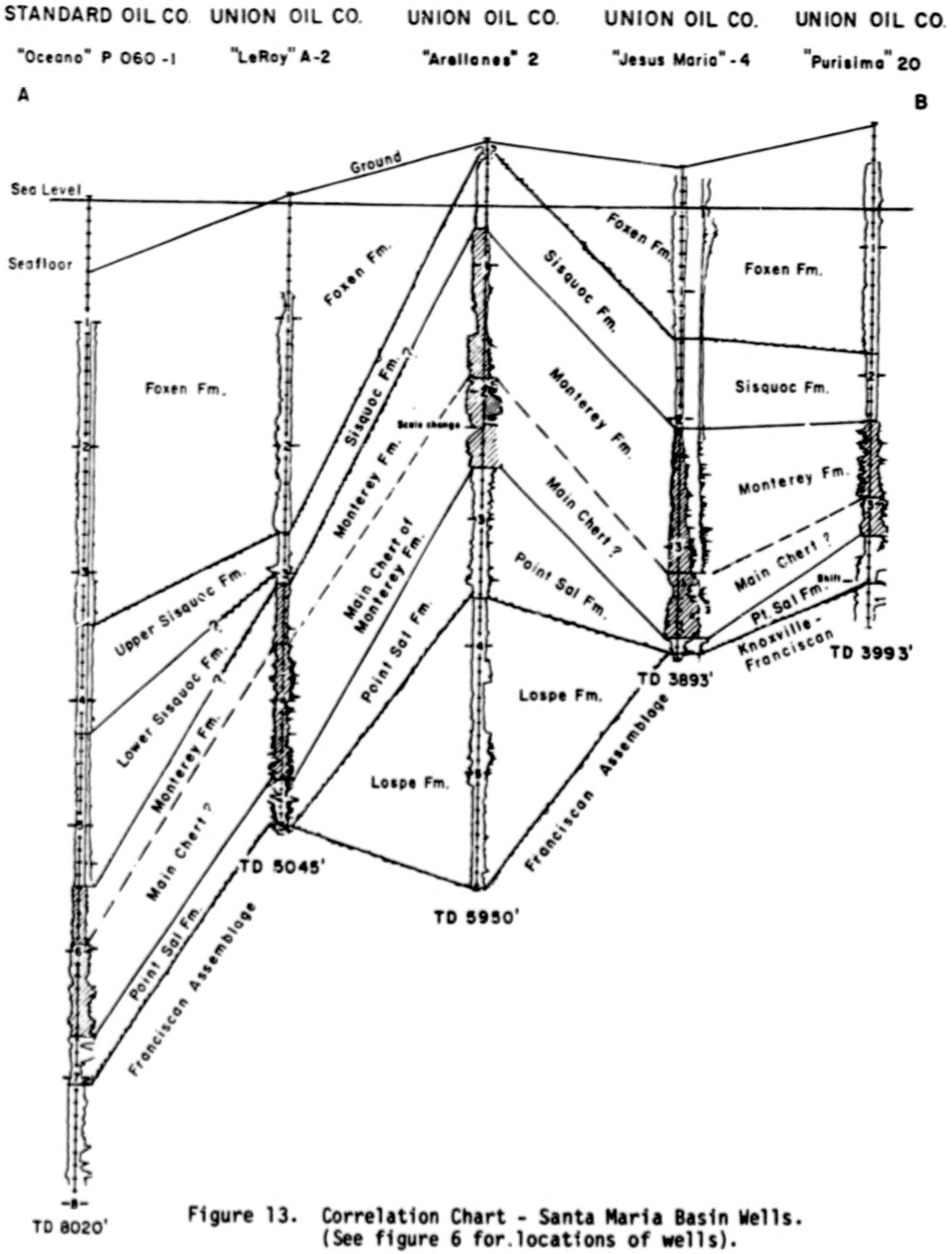

Figure 13. Correlation Chart - Santa Maria Basin Wells. (See figure 6 for locations of wells).

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about 14.5 miles northwest of Point Sal in 550 feet of water. It was abandoned on January 7, 1965, at 8,020 feet total depth in metamorphosed sediments and volcanics of the Franciscan Assemblage (fig. 13; fig. 7. col. 6). The well penetrated Quaternary beds and Pliocene age Foxen Formation from the seafloor to 3,400 feet, Sisquoc Formation of late Miocene age to 5,485 feet, Monterey Formation to 6,660 feet, Point Sal and Obispo sediments and volcanics of Miocene age to 7,060 feet, questionable early Paleogene beds to 7,060 feet, and Franciscan basement rocks to total depth. The first weak oil shows were found in siltstone in the lower part of the post-Miocene Foxen Formation from 3,040 to about 3,400 feet. A few scattered shows of tar in siltstone fractures were noted in the Miocene above the Monterey, but the Monterey Formation had shows throughout. The strongest shows were below 5,950 feet in the cherty Monterey and consisted of tar in fractures, sour-gas odor, brown to dark brown cut, and blue-white to yellow fluorescence, indicative of heavy to medium gravity oil. Some tar on fractures in the volcanics of the Point Sal Formation below the Monterey was also noted. No formation tests were run.

The economic climate for heavy sour crudes, the type of reservoirs (fracture-dependent porosity), production histories of analog fields in the onshore Santa Maria basin, processing requirements (high sulphur, low gasoline, high asphalt fractions), and high production and transportation costs determined that Monterey Formation oil would not be economic in the offshore environment at that time.

A NEW LOOK AT THE MONTEREY FORMATION

Since relinquishment of all the 1963 leases, oil production from the Monterey Formation has been developed in the Santa Barbara Channel on both State and Federal offshore leases, and more recently, on Federal OCS leases in the Santa Maria basin offshore. In 1969, oil was discovered in the Monterey Formation at the Hondo structure in the Santa Ynez Unit of the Federal OCS in the Santa Barbara Channel. In 1986, more than 11 million barrels of oil and 10.4 billion cubic feet of gas were produced from Hondo platform. Cumulative total production from inception to the end of December 1986, was 69.8 million barrels with an estimated 132 million barrels of reserves. Thus the total ultimate production was estimated at 202 million barrels (California Division of Oil and Gas, 1987). An additional platform, "Harmony", is scheduled for the Hondo field, and 3 platforms for Sacate and Pescado fields are planned for the Santa Ynez unit, including scheduled platforms "Heritage" and "Heather."

Oil was discovered in the Monterey Formation in the offshore portion of the Santa Maria basin on two leases obtained in OCS Lease Sale 48 held on June 29, 1979. These discoveries were determined to be on the structure subsequently named the Point Arguello oil field. The field was later extended northward onto leases from Sale 53, held on May 28, 1981, which brought in a total of $2,036,954,089. The highest bonus for a single tract in Federal OCS history was $333,596,200, paid for one of them, OCS-P0450. Delineation drilling confirmed a giant oil field, with estimated reserves in excess of 300 million barrels of oil (Crain and others, 1985). The first well tested at a rate of 6580 B/D (barrels per day) of oil and 1680 Mcf/D (thousand cubic feet per day) of gas from a 1,075 feet section of fractured reservoirs of Monterey Formation. Gravity of the oil from tests of the first several wells ranged from 18.2° to 33.2° API (Crain and others, 1985).

Three platforms, "Harvest," "Hermosa," and "Hidalgo", are in place, and drilling is underway on the first two. Peak production from one of the platforms is expected to be 39,000 barrels of oil daily, and the combined daily production expected from the other two is 57,000 barrels of oil (Rintoul, 1987).

The Point Pedernales field, located 4 1/2 miles west from shore and 16 miles west of the city of Lompoc, is the first field on Sale 53 leases to be put on production. It was discovered by Union Oil Company in January 1983 (Rintoul, 1987). Since Platform Irene was put on production in March 1978, authorized capacity of 20,000 barrels of oil per day has already been attained, and the operator, Union Oil Company, is seeking approval for 25,000 barrels per day production from the platform. Only 12 wells of the 72 slot platform are being utilized. Platform Independence is in the planning stages for an adjoining tract in the field. The field has so far been confirmed on three tracts, with reserves estimated at more than 300 million barrels of oil from fractured Monterey Formation (Pacific Oil World, 1987). Oil gravity is 15°-16° API in the field.

The San Miguel oil field, discovered by Occidental Petroleum Corporation in January 1983, is located about nine miles west of the coastline at Point Sal. The 70 slot Platform Julius is expected to be installed in late 1987 and producing before the end of 1988. Reserves for the field are estimated at 300 million barrels of oil. The 12° API graviity crude will go to an existing Union Oil Co. refinery in San Luis Obispo County, then by the All American Pipeline to Texas (Rintoul, 1987).

Six additional fields have been discovered in the Santa Maria basin offshore (Raftery and Wolfson, 1987), which, with the more than 900 million barrels of oil estimated reserves in the three giant fields discussed above, indicate in excess of a billion barrels of discovered oil in the basin, from the fractured rocks of the Monterey Formation.

Since the announcement of the discoveries in the Santa Maria basin, operators are taking another look at the Monterey Formation on State tidelands leases in the Santa Barbara Channel, and the State Lands Commission Report to the Legislature in December 1981 proposed a 40,000 acre tidelands lease sale extending from Point Arguello to Point Conception.

The geology, oil shows, and log characteristics of wells in most of the basins of central and northern California are similar to those in the Santa Maria basin. These similarities indicate that the presence of several undiscovered giant oil fields in central and northern California, comparable in size and quality to the Santa Maria basin fields, is highly probable.

GLOSSARY

Algae - photosynthetic, chiefly aquatic plants that lack true stems, roots and leaves. Includes kelp and other seaweeds.

Analog field - An oil or gas field with known geologic parameters that occurs in a similar geologic environment.

API gravity - the standard American Petroleum Institute method of specifying the density of crude oil.

Asphaltic crude oil - a crude oil which, upon processing, yields relatively large amounts of asphaltic residues.

Basement - a complex of rocks lying beneath dominately sedimentary rocks. Basement rocks are characteristically dense and hard with very poor porosity and permeability.

Basin - a large segment of the earth's crust which has been downwarped and where sediments accumulate.

Bleeding oil - crude oil seeping from rock pores. An expression commonly used to describe rock cores.

Bonus - the dollar figure paid by the lessee for the execution of a Federal offshore oil and gas lease.

California Coordinate System (Lambert) - A method of offshore mapping whereby the area is divided into blocks, three miles on a side.

Chert - a very dense, hard, dull to semi-glassy sedimentary rock consisting of crystalline silica. The crystals are generally too small to be recognized under an ordinary microscope.

Conglomerate - a sedimentary rock composed of rounded fragments larger than 2 mm in diameter set in a fine-grained matrix of sand, silt, or any common natural cementing material.

Cryptocrystalline - texture of a rock having crystals too small to be recognized under the ordinary microscope.

Cut - visible oil from well cuttings dissolved in a solvent.

Dead oil - solid petroleum such as asphalt which has lost its liquid and gaseous fractions.

Diagenetic changes - physical and chemical changes in a sediment after deposition that convert the unconsolidated sediment to consolidated rock.

Diatom - a microscopic, single-celled plant living in marine or fresh water. Diatoms secrete siliceous skeletons of great variety of form.

Drill stem test (DST) - a test of the productive capacity of a well while the drill hole is still full of drilling mud. The test tool is attached to the drill pipe.

Fluorescence - emission of visible light from oil which has been exposed to ultraviolet light.

Foraminifera - single-celled animal, mostly of microscopic size that secrete external shells of calcuim carbonate, or builds them of cemented sedimentary grains. Most are marine.

Formation test - a test of the productive capacity of a well.

Fracture gradient - pressure necessary to cause rocks to fracture; increases with depth. It is generally expressed in pounds per square inch per foot of depth.

Franciscan assemblage - sedimentary and volcanic rocks which have been deposited exclusively in deep basins on oceanic crust and whose age varies from late Jurassic to early Cretaceous (a subduction complex).

Giant oil field - an oil field whose ultimate recoverable oil reserves are 500 million barrels or more.

Heavy oil - oil with gravity less than 20° API.

High gravity oil - oil with gravity between 34° and 50° API.

Hydrocarbon - any organic compound, gaseous, liquid, or solid, consisting solely of carbon and hydrogen.

Light oil - see high gravity oil.

Lipids - a broad term that includes all oil-soluble, water-insoluble substances such as fats, waxes, fatty acids, etc.

Metamorphic rock - a rock that has been significantly altered from its original state by changes in pressure, temperature, or chemical environment.

MMcf - million cubic feet.

Molecular water - diatom remains are composed of amorphous silica combined with molecular water. During diagenesis (change from amorphous silica to quartz), the molecular water is released.

Mud weight - weight of drilling mud expressed in pounds per gallon or pounds per cubic foot.

Oil reserves - recoverable oil estimated from geologic evidence supported directly by engineering measurements.

Oil sand - sandstone reservoir containing oil.

Oil shale - a kerogen-bearing, finely laminated brown or black shale that will yield liquid or gaseous hydrocarbons on distillation.

Opaline silica - opal-like metastable form of silica composed of interlayered a-cristobalite and a-tridymite.

Organic material - material consisting primarily of the remains of living organisms (plant or animal).

Outer Continental Shelf (OCS) - all submerged lands lying seaward of the state offshore lands. The boundary between the OCS and state offshore lands in the Pacific Ocean lies three geographic miles offshore.

Radiolarian - marine protozoans that possess complex internal siliceous skeletons.

Reservoir rock - any rock with adequate porosity and permeability or joint and fracture systems to contain liquid or gaseous hydrocarbons.

Sandstone dike - a tabular mass of sedimentary material that cuts across the structure or bedding of preexisting rock.

Santa Ynez Unit - unit formed in the northwestern part of the Santa Barbara Channel by Exxon. A unit combines two or more leases for the orderly development of an oil or gas field which lies within more than one lease.

Schist - a metamorphic rock with sub-parallel orientation of the micaceous minerals which dominate its composition.

Semi-submersible vessel - a floating, offshore drilling vessel that has hulls submerged in the water but not resting on the seafloor. The submerged hulls give stability to the vessel.

Shows - indications of the presence of hydrocarbons in a rock.

Silica phase transformation - the transformation of biogenetic silica to Opal-CT to diagenetic quartz by burial and increased temperature and pressure.

Sill - a tabular igneous body that parallels the planar structure of the surrounding rocks.

Sour crude oil or gas - containing noticeable quantities of noxious sulfur compounds.

Source rock - a fine-grained sedimentary rock with high organic content capable of generating an accumulation of oil or gas.

Spud - to begin drilling a well.

Tar sand - a sandstone from which the lighter fractions of crude oil have escaped, leaving a residual asphalt to fill the interstices.

Turbo-drill - a drilling tool that rotates a bit attached to it by the action of the drilling mud on the turbine blades built into the tool. Often used for directional drilling.

Universal Transverse Mercator System - a method of offshore mapping whereby the area is divided into blocks, 4,800 meters on a side. Each regular block contains 2,304 hectares.

Volcanics - finely crystalline or glassy igneous rocks resulting from volcanic action.

Wire line formation test - a hydrocarbon productivity test of a formation accomplished by lowering a testing instrument into the well by a wire line.

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March 3, 1849

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